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Feasibility Study

of an integrated

Mobile Data Collection Platform

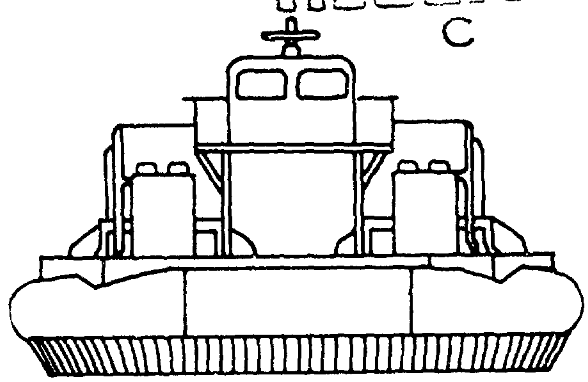
using an

Air Cushion Vehicle

by
J. A. Hatchwell and R. A. Lenton
(U)

Technical Report

May 1972



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VOLUME I

A FEASIBILITY STUDY OF AN INTEGRATED MOBILE DATA COLLECTION PLATFORM USING AN AIR CUSHION VEHICLE

(U)

FINAL TECHNICAL REPORT

By

J. A. Hatchwell, Principal Investigator
and
R. A. Lenton

Prepared for
OFFICE OF NAVAL RESEARCH -- ARLINGTON, VIRGINIA
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13. ABSTRACT

This is a study report on the feasibility of using the Bell Aerospace Company air cushion vehicle (Voyageur) as a mobile data collection platform in the Arctic. Specifically, the report covers seven areas where this vehicle would serve usefully in support of Naval Arctic Research Laboratory activities.

Operational costs of the vehicle are compared with those of other vehicles currently being used in the Arctic. The comparison shows the air cushion vehicle to be competitive with other vehicles in many research investigations, resupply missions, and data collection efforts.

A complete description of the vehicle is given in an appendix, along with its special operating parameters.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. AIR CUSHION VEHICLE						
2. SURFACE EFFECT VEHICLE						
3. ARCTIC MOBILE DATA COLLECTION PLATFORM						
4. HOVERCRAFT (BELL AEROSPACE CO.)						

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SECTION I

INTRODUCTION

During the investigation conducted for ARPA to analyze and evaluate system concepts for the collection and dissemination of arctic scientific information, the requirement for suitable data collection platforms became apparent. Due to the constantly changing environment and the harsh climatic conditions of the arctic region (above the Arctic Circle), the need for an amphibious vehicle (i.e., one that could rapidly traverse a nonhomogeneous pathway over tundra, fast ice, sea ice, and water) became apparent. However, the vehicle or platform had to meet an all-season operational status to fulfill a continuing need for monitoring the varying parameters of the ever-changing environment.

In the subsequent search for a platform and/or vehicle, it appeared that the air cushion vehicle (ACV; also known as a surface effect vehicle, SEV; or hovercraft machine) seemed to generally match the above specifications. Further, earlier models of ACVs have been tested in various locations in Alaska and on the northern continental shelf. One of these tests consisted of a 2-week demonstration of an SK-5 ACV configured to acquire hydrographic information in the marginal ice zone (MIZ) approximately 100 miles north of Point Barrow, Alaska. The Army at Fort Greely, Alaska has been testing the military stretch version of an SK-5 over frozen river routes and in mountain passes. Preliminary indications from conversations with the officer-in-charge of the Army's SEV evaluation team point to the vehicle's ability to easily overcome reasonable path obstacles on river routes and to climb slopes of 10 to 15 percent grade into snow-covered mountain passes.

With this performance record as a background, it was determined that an ACV holds considerable promise as an all-season data collection platform which could be operated by NARL from Point Barrow to support primary scientific data collection missions and to carry out logistic support operations when not performing its primary mission.

This study analyzes potential ACV applications based on a survey of the needs of key scientists and arctic investigators. The vehicle configuration used will be based on the Bell Aerospace flatbed Voyageur (a prototype model is currently being certified by the Canadian government and will soon undergo an 18-month field evaluation in the Mackenzie delta).

For each mission profile covered in this report, fixed and operating vehicle costs and logistic ground support services will be determined and assessed. Cost comparisons and technical trade-offs will be performed, resulting in specific recommendations of vehicle selection and the optimum configuration to service NARL needs.

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Naval Arctic Research Laboratory

The Naval Arctic Research Laboratory is located on the Arctic Ocean coast 4.1 miles northeast of Barrow, Alaska at the site of the former Exploration Base Camp of Naval Petroleum Reserve Number 4 and is operated by the University of Alaska under contract with the Office of Naval Research. The Office of Naval Research retains twenty tracts of land and some former DEW sites throughout the North Slope of Alaska and the Brooks Range which are utilized by NARL as research sites. (See Figure 1.)

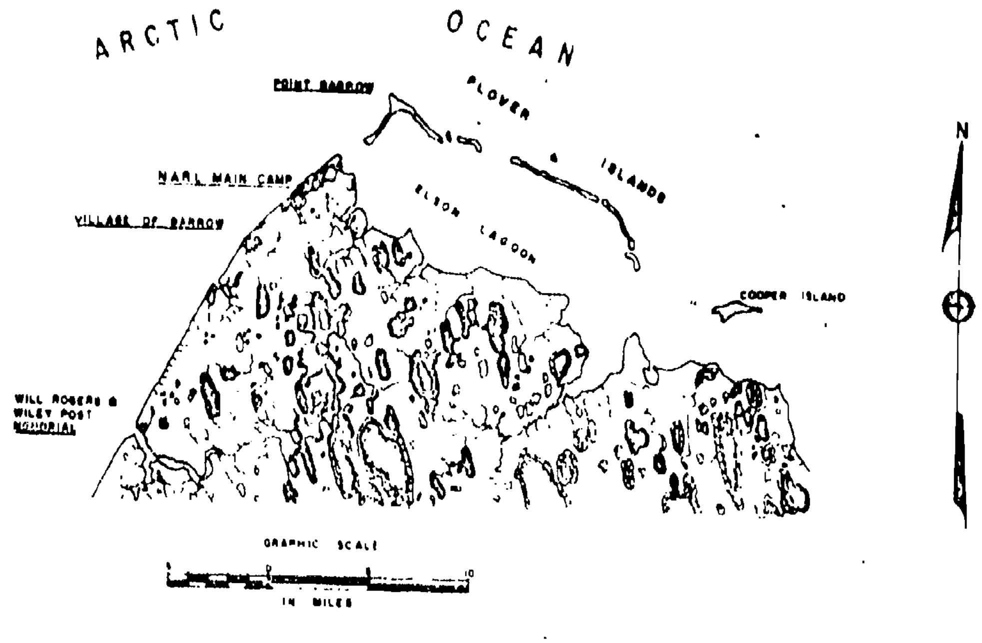


Figure 1. NARL Location Map

SECTION II

CONCLUSIONS AND RECOMMENDATIONS

Vehicle Preference and Configuration

Of the several air cushion vehicle manufacturers surveyed for available craft to meet the mission requirements of this study, Bell Aerospace appears to be the only manufacturer with an ACV (#001 Voyageur) immediately available that satisfies the payload (weight) and space needs of the integrated scientific mobile data collection platform.

The modular approach of installing off-the-shelf easily removable shelters offers versatile configurations to satisfy all planned mission requirements. The use of modules is the most efficient and cost-effective approach to outfitting this platform for scientific and general missions.

The Voyageur is designed to withstand the rigors of the arctic environment, and it is the only available platform that satisfies the all-season operation requirements of this study.

Existing base facilities at NARL are adequate for logistic support requirements -- hangar space, fuel storage, repair shops, and ground handling equipment. It would be desirable to purchase a mobile travel lift for making major skirt replacements and hull repairs and for relocating the craft during main power plant failures.

Although the Voyageur #001 is a prototype engineering model of the Voyageur Series, it has been through a "shakedown" cycle, with over 700 hours of logged operating time.

Mission Capabilities

The Voyageur (#001 or #003) is technically suited to handle the following primary missions within a 150-nautical-mile radius of NARL:

- Bottom sampling
- Automatic data buoy deployment and MIZ operations
- NARL resupply lighterage
- AIDJEX satellite camp ferry operations
- Sea ice profiling
- Bering Sea oceanographics
- NARL field station resupply

In addition, preliminary investigations of other mission profiles indicate the ACV can be programmed for coastal fast ice investigations and for Ice Island T-3 resupply and personnel transport (withing the operating range constraints of the ACV).

Operational Cost Effectiveness

Each primary mission has been costed and compared to existing arctic transports (see Table I). The results indicate that, under ideal operating conditions (good flying weather), the AIDJEX satellite camp and NARL resupply missions by ACV are not cost competitive with other airborne transports. Considering the all-season operating capability of all types of arctic platforms, the air cushion vehicle has no competition.

Implementation Plan

Since Voyageur #001 is the only vehicle available that is suited for the overall mission requirements, and since the earliest delivery commitment Bell Aerospace will make on Voyageur #003 and later production models is 12 to 14 months from the receipt of a bona fide order, it is recommended that ONR consider acquiring vehicle #001 to take advantage of the timely opportunity of scheduling the ACV for the maximum number of missions through the arctic winter season. A 9-month potential vehicle mission assignment is detailed in Section VII.

Vehicle Purchase Versus Lease

Based on Bell Aerospace's outright purchase and lease-buy back plans, the pro rata vehicle daily and hourly costs indicate the most favorable and economical approach is to purchase Voyager #001. Capital investment for the vehicle would be $850,000 with spares and necessary modifications totaling an additional $232,000. Predicated on the manufacturer's estimate of a 10-year life cycle, the fixed annual investment is $325,310. Fixed costs prorated are $212 per hour or $1,710 per day.

The lease-buy back plan is offered for 12 months, 18 months or 24 months with an option to purchase the vehicle at the end of these respective periods. In all instances the leasing rate is $29,200 per month. At the end of the 12-month lease, the craft can be purchased for $575,000; after 18 months, the price is $530,000; and after 24 months, the price is $485,000. The minimum lease offered by Bell is 12 months.

For the lease plan, the prorated hourly assesment for the use of Voyageur #001 is $396 per hour or $3,160 per day. These pro rata charges are based on a 2-year minimum lease period and an 8-hour working day.

Should ONR desire to forego substantial capital investment in such a vehicle, the 2-year leasing plan exercising no purchase option is recommended.

TABLE I

COST COMPARISONS FOR MISSIONS

Mission	ACV		Helicopter	Icebreaker	Other
	Purchase	Lease			
Bottom Sampling (winter operation)	$ 5,466	$ 9,816	$10,416	$ 32,000	
Data buoy deploy MIZ operations	14,881	23,700		140,000	
NARL resupply lighterage	14,475*	23,900*			NARL Cool Barge backhaul **
AIDJEX Satellite Camp resupply and ferry	1,970	3,420	603		$1,077 (Twin-Otter)
Bering Sea oceanographics	30,169	52,644		120,000	
Sea ice profiling (winter operations)	14,592	23,292			$220,000 (Birdseye/submarine/drift station)
NARL field resupply No. 2	7,890	13,690			$11,200 (C-130)
No. 3	3,945	6,845			$ 1,672 (R4D)

* 24-hour operation

** Costs not available

SECTION III

VEHICLE DESCRIPTION AND CONFIGURATION

Introduction

Numerous studies and arctic trials have shown the technical potential of the ACV. In this study of the use of a large ACV as a mobile data collection platform for scientific research in the Arctic Basin, the currently designed commercial Bell Aerospace Voyageur (Model 7380) flatbed craft was chosen primarily because it is the only ACV in its class and payload that is available for lease or purchase. This vehicle appears to offer economic advantages over other means of arctic transportation when utilized as a mobile scientific base.

The Voyageur is a flatbed craft which allows rapid handling of a variety of cargoes. It also permits the addition of superstructures to meet the requirements of a self-contained, highly mobile laboratory for up to nine men (six scientists and three crew members).

The basic vehicle is constructed in modular form so that it can be transported via C-130 Hercules aircraft for assembly on site. Individual hull structural modules are designed around the use of welded 6000 Series aluminum extrusions. These extrusions are in the form of hollow core planking and joint sections. On final assembly, bolted splice plates are used to structurally join the modules.

The two available craft differ primarily in their engine installations. The first (#001) is powered by two General Electric LM-100 engines and the second (#003) by two Pratt and Whitney ST 6T-75 Twin-Pac engines. Each engine installation drives, through appropriate gearing, a Bell SK-5 centrifugal lift fan and Hamilton Standard propeller. The ST 6T-75 installations will provide 4-engine reliability as well as increased thrust.

The control cabin is supported on a simple truss structure and located toward the rear of the craft. The cabin provides comfortable seating for the vehicle operator and for an assistant operator/navigator or radar operator. Instruments, communications, controls, and radar systems are located for accessibility and reduction of operator fatigue. Large windows assure an unobstructed view in all directions.

The main deck is designed to accept loadings up to 1,000 pounds per square foot. When the vehicle is off-cushion, the cargo deck is low enough to permit rapid loading or unloading from trucks or forklifts and C-130 Hercules aircraft. Cargo tie-down rings are provided and are located in four rows 104 inches apart and spaced every 33 inches along the row. Each ring

has a load capacity of 15,000 pounds. The rings may be used in combinations for hoisting the craft with appropriate slings. Access to the control cabin is provided by ladders and walkways.

The craft is completely amphibious, with the hull being divided into separate watertight compartments with a reserve buoyancy in excess of 100 percent. The trunks and skirts are designed for minimum air leakage. Skirt materials are made of neoprene covered nylon fabric to give extremely long life when traveling over land, ice, or water. The general arrangement of the basic Voyageur is shown in Figure 2 and the leading particulars and weight summary of Vehicles #001 and #003 are in Tables II and III respectively. The design meets or exceeds Air Cushion Vehicle Regulations and Certification Requirements of the U.S. Coast Guard. A comprehensive description of the Voyageur 7380 is included in Appendix A.

Mobile Laboratory Configuration

To equip the Voyageur ACV as a mobile laboratory and data collection platform, several sources were investigated for lightweight modules which could be readily purchased to serve as housing, messing, and laboratory facilities.

The module requirement is for a unit to be skid mounted with sufficient structural strength to withstand being on- and off-loaded many times from the vehicle. It should be a self-contained unit constructed of the lightest durable materials available with built-in fittings for easy lifting by crane or helicopter. To make it completely operational would require only cable coupling to an external electrical power source.

From the manufacturers surveyed, the lightweight, off-the-shelf modules of the Model 040 Series of helicopter transportable units made by ATCO Industries for specific application to arctic environments were found to be most desirable.

The available deck space of Voyageur Model 7380 is 40 by 32 feet (1,280 square feet). The basic housing and messing accommodations are provided by the three rear modules (Figure 3) consisting of:

1. Kitchen/diner, Model 040-053, 16 by 9 feet, 3,800 pounds.
2. Sleeper (8-man), Model 040-013, 18 by 9 feet, 3,530 pounds.
3. Washroom/generator, Model 040-113, 16 by 9 feet, 3,425 pounds.

When positioned as shown in Figure 3, these modules would provide a compact living area with adequate space for eight men.

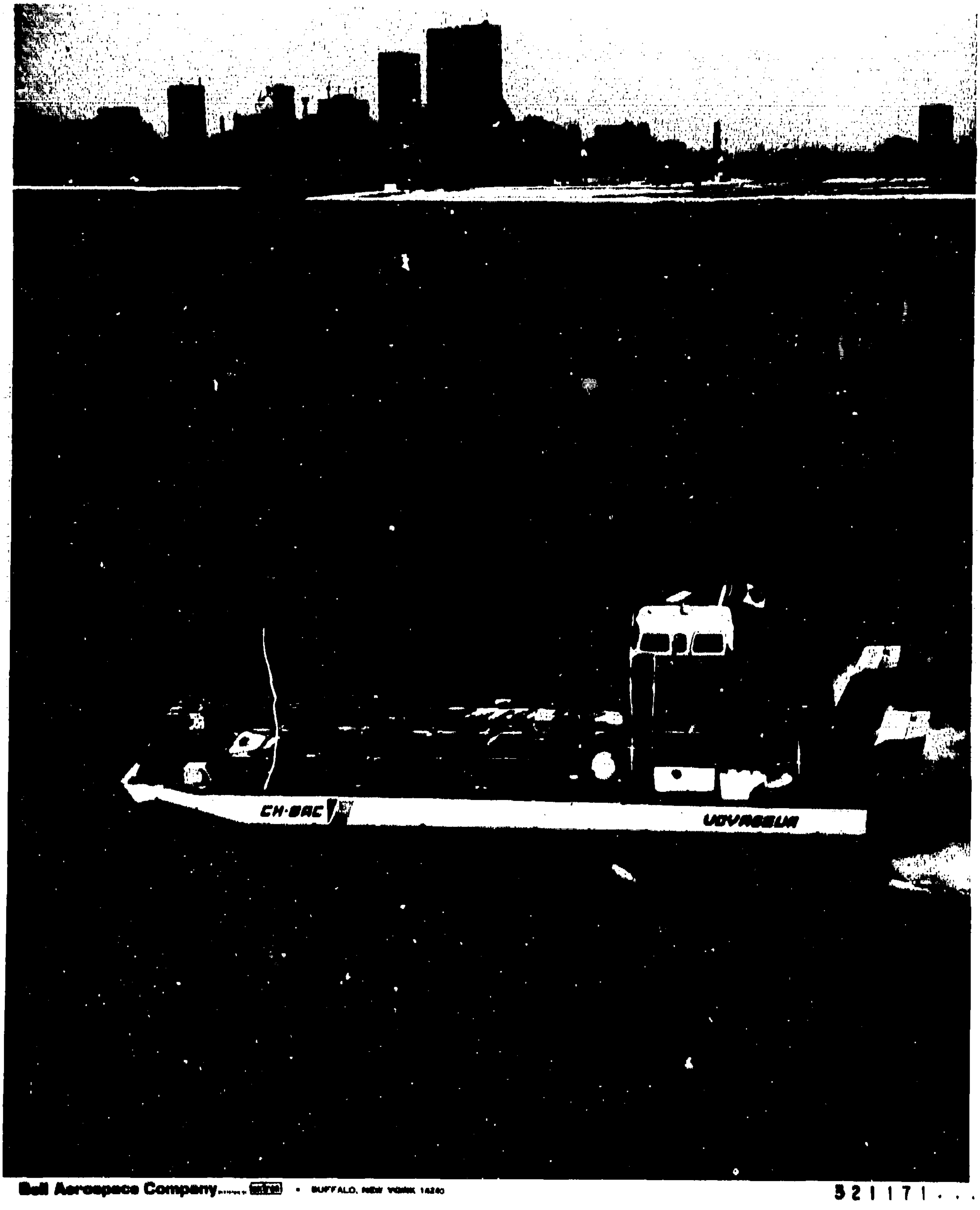


Figure 2. General Arrangement of the Voyageur

TABLE II

VOYAGEUR MODEL 7380 SPECIFICATIONS*

Dimensions		
Length, overall	64.8 ft	
Beam, overall	36.7 ft	
Height, overall (on-cushion)	22.0 ft	
Height, overall (off-cushion)	18 ft 10 inches	
Height of cargo deck (off-cushion)	3 ft 10 inches	
Skirt height, nominal	4.0 ft	
Cushion area	1,789 sq ft	
Cushion loading at 88,000 lb	49.2 lb/sq ft	
Buoyancy reserve at 88,000 lb	125%	
Cargo deck	40 x 32 ft (1,280 sq ft)	
Propellers		
Propellers (2)	Hamilton Standard, Model 43D50, 3-bladed 9 ft dia, controlled pitch	
Lift fans (2)	7 ft dia, 12-bladed, fixed pitch, centrifugal	
Flexible trunks	4 ft combination type with 50% fingers	
Fuel System		
Type	Standard aviation kerosene (AVTUR) JP4 or JP5	
Tanks	Six in groups of three	
Capacity	2,400 U.S. gallons	
Boost pumps	Vane type, 120 U.S. gallons/hr	
Electrical System		
Generators (4)	Gearbox driven brushless, supply 28 vdc	
Batteries (2)	Nickel-cadmium, 28 volts	
External power	28 vdc	
Power Modules	**Vehicle #001**	**Vehicle #003**
Engines	Two General Electric LM-100 PD-101 Marine Gas Turbines	Two United Aircraft of Canada Pratt and Whitney ST 6T-75 Marine Gas Turbine
Transmission (2)	Integrated drive for lift fan and propeller	Speco, integrated drive for lift fan and propeller

* The information in this table is supplied by Bell Aerospace Company and is proprietary.

TABLE III

VOYAGEUR MODEL 7380 WEIGHT SUMMARY*

Item	Vehicle #001 (Pounds)	Vehicle #003 (Pounds)
Basic structure	21,039	21,733
Crew station	2,459	2,459
Propulsion system	5,016	5,711
Electrical system	431	612
Controls	94	102
Skirts, landing pads	3,596	3,667
Fins and rudder	147	147
Exterior finish	349	349
Furnishings	647	670
Miscellaneous	118	118
Weight empty	33,896	35,568
Fuel, 2,400 U.S. gallons	16,320	16,320
Weight fueled	50,216	51,888
Payload	37,784	36,112
Maximum permissible gross weight	88,000	88,000

* The information in this table is supplied by Bell Aerospace Company and is proprietary.

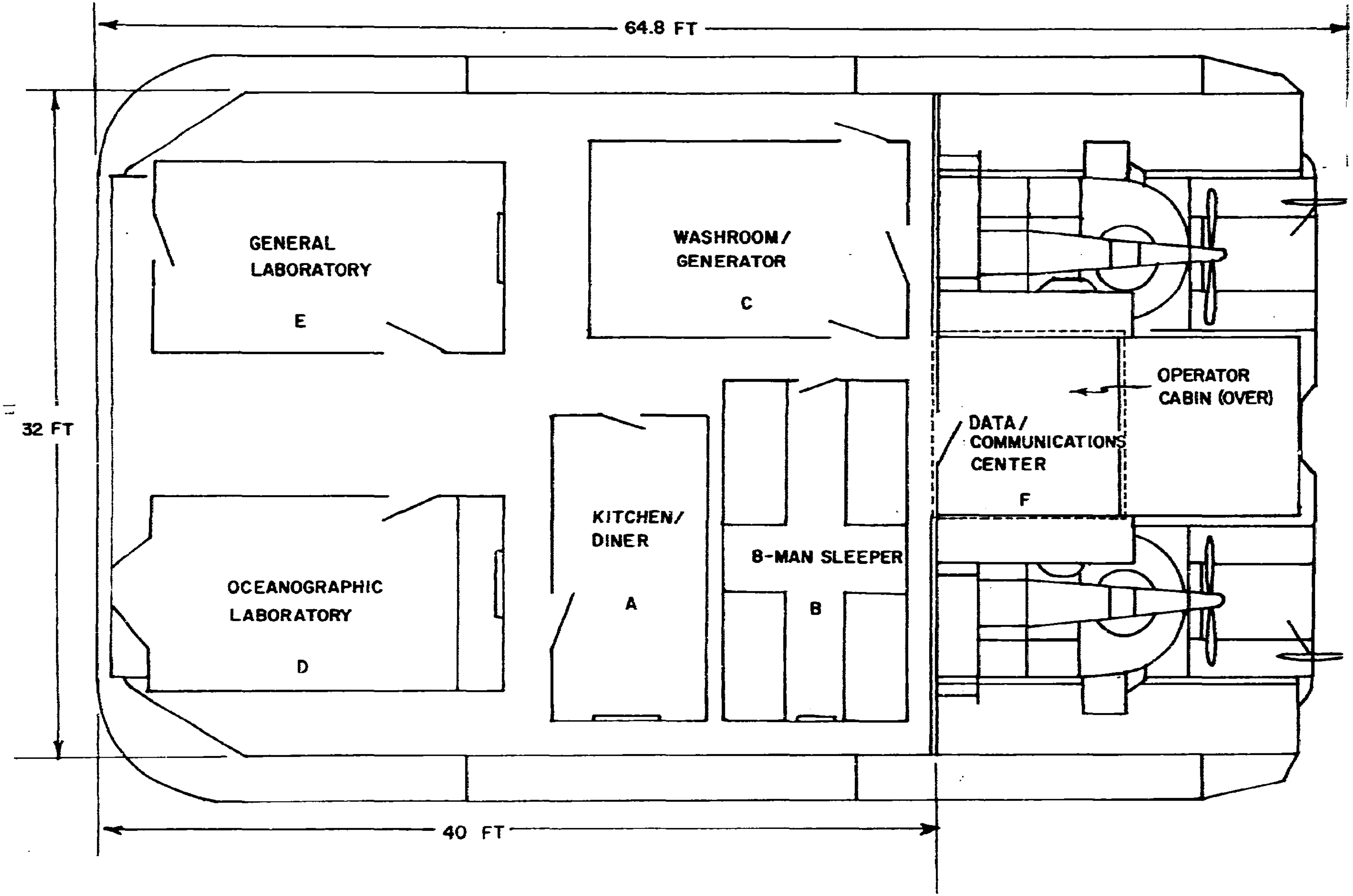


Figure 3. Configuration of Modules for Proposed Mobile Laboratory

The kitchen/diner (Module A, Figure 4) comprises an off-the-shelf ATCO kitchen unit with certain modifications. These modifications affect only the internal layout and are easily accomplished by the manufacturer. A unit with this layout has been used on the North Greenland ice sheet, where it proved adequate for 10 men, with a maximum of 16 men for brief periods. An electric range is normally supplied by the manufacturer. In considering certain scientific missions where quiet periods are necessary, it is recommended that a propane range be used. The seating arrangement utilizes a bench-type seat which can be used as a bed in emergencies. Storage space for food is beneath the seat. Nominal electrical power requirement for the module is 4.75 kilowatts (115 vac, 60 cycles).

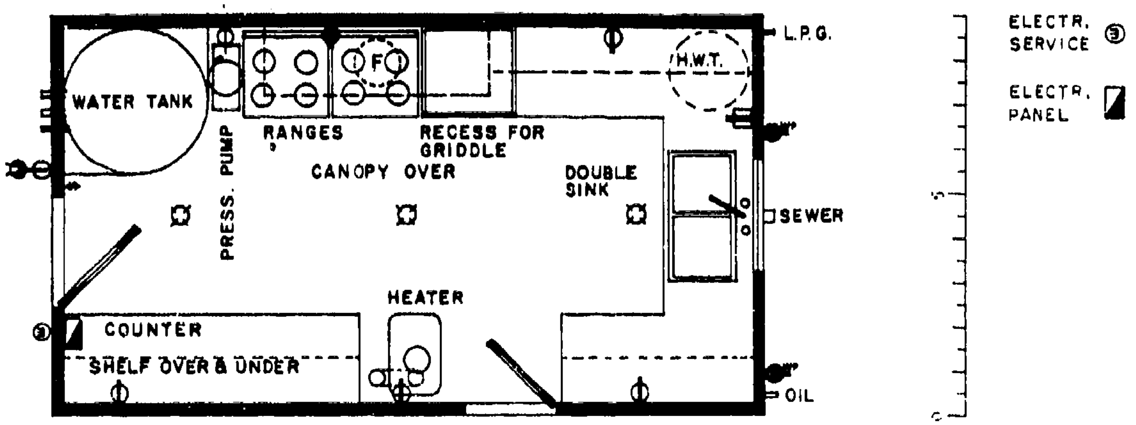
The sleeper (Module B, Figure 4) is a standard unit equipped with an oil-fired, forced air heater, a double closet with drawers and curtains, four double bunks with 4-inch foam mattresses and covers, a night table, and stack chairs. Nominal electrical power requirement is 1 kilowatt (115 vac, 60 cycles). A storm window of the escape type (18 inches high by 30 inches wide) is located at one end of the module, with an entrance door at the other end.

The washroom/generator (Module C, Figure 4) is a standard ATCO module requiring the installation of a shower unit and washstand. In the arrangement shown in Figure 4, this module is located for easy access for refueling the diesel tank, for venting the generator exhaust, and for drainage of waste water over the starboard side. The toilet should be the chemical type and enclosed by curtains. Nominal electrical power requirement is 2 kilowatts (115 vac, 60 cycles).

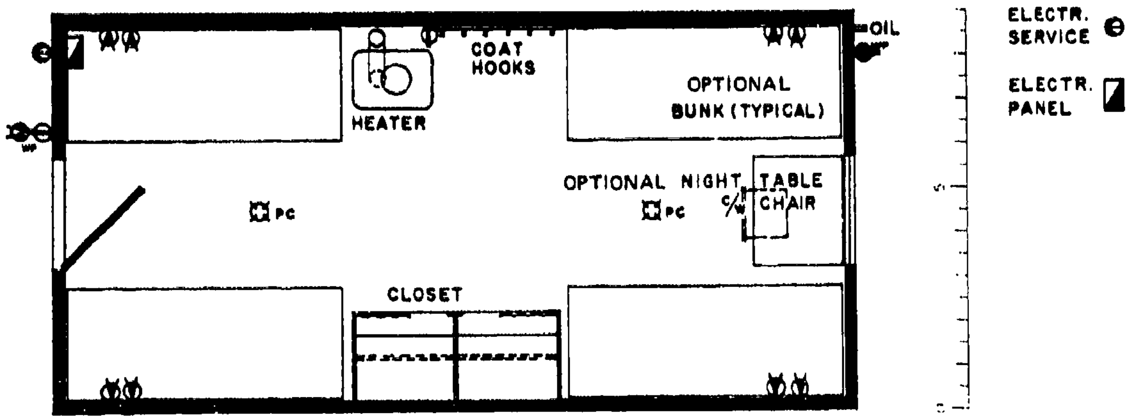
The remaining deck space (640 square feet) will be used for laboratory and workshop modules.

The oceanographic laboratory (Module D, Figure 5) will have space for installation of a general-purpose hydrographic winch and accessories. Operation of the winch will be accomplished through the double door opening at the foot of the module. The built-in bench can be used as an instrument preparation table. Final configuration of the module (storage racks for Nansen bottles, current meters, reversing thermometers, etc.) can be completed at NARL. Nominal electrical power is 2 kilowatts (115 vac, 60 cycles). This does not include instrument electrical power requirements.

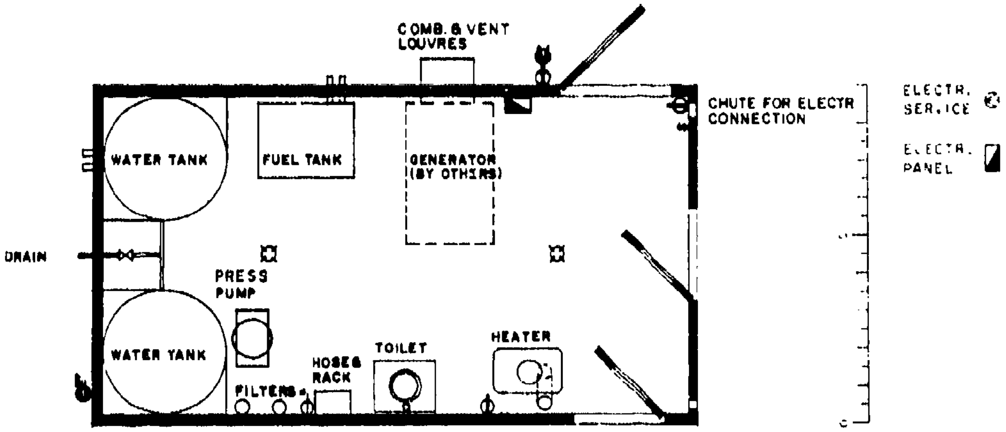
The general laboratory (Module E, Figure 5) should be fitted out by NARL carpenters to suit the needs of investigators. Several of these modules could be purchased and configured in different ways to accommodate the discipline involved (i.e., acoustics, electronics, marine biology). Nominal electrical power for this module is 1 kilowatt (115 vac, 60 cycles). This does not include instrument electrical power requirements.



MODULE A: Kitchen/Diner (Module 040-053)

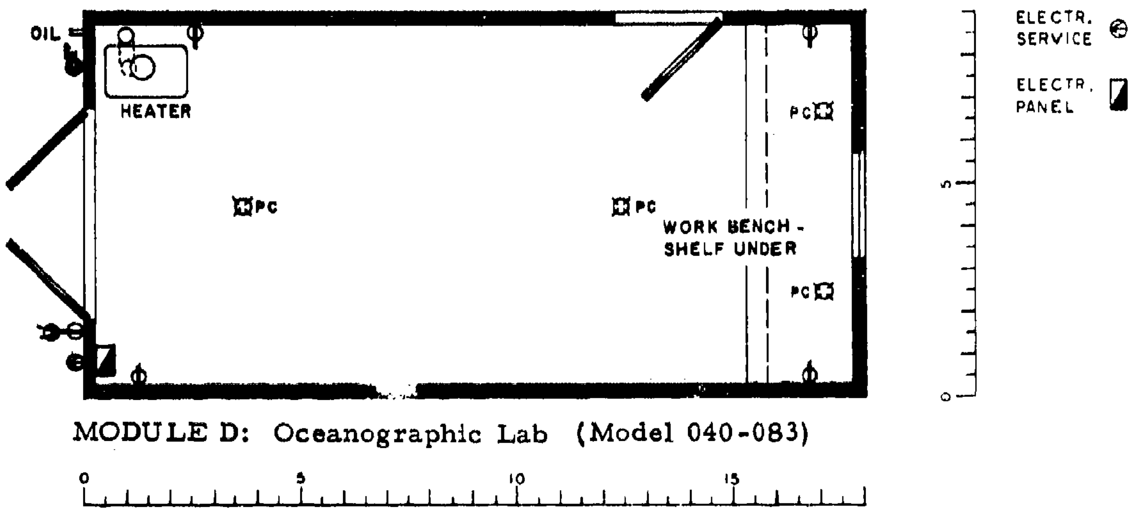


MODULE B: 8-Man Sleeper (Model 040-013)

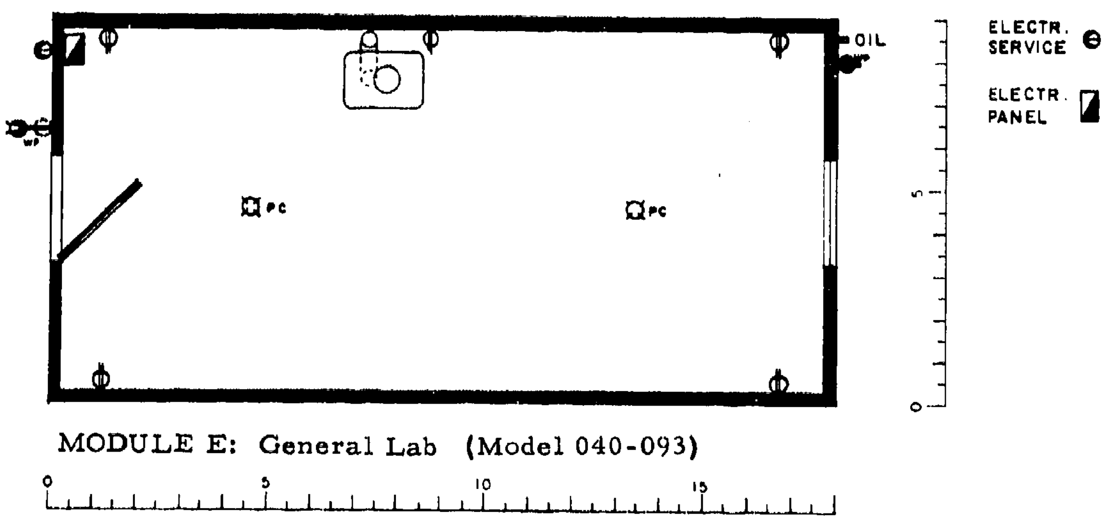


MODULE C: Washroom/Generator (Model 040-113)

Figure 4. Detailed Layout of Modules



MODULE D: Oceanographic Lab (Model 040-083)



MODULE E: General Lab (Model 040-093)

Figure 5. Detailed Layout of Modules

In addition to the above modules, there is a requirement for a data recording station and communication/navigation center. The area under the control cabin and to the rear (Figure 3) will be utilized for permanently mounting this center. The module will not be an off-the-shelf item, but instead will be specially constructed to fit the space available. The interior rack mountings, bench layout, and tape storage racks will be fitted at NARL. Remote control positions for radio and navigation equipment will be fed from the center to the control cabin. Heating will be provided by bleed-off from the hot air heaters for the control cabin.

The weight budget of the proposed configuration is give in Table IV.

Alternate Configurations

The use of interchangeable modules for the Voyageur ACV provides alternate configurations that give greater flexibility and use of the vehicle. By removing Modules A through E (Figure 3) the vehicle would be presented as a flatbed carrier (Figure 2). In this configuration, it could be utilized as a cargo carrier for lighterage during the annual resupply operations and as a bulk cargo carrier for supply operations to NARL field sites.

Consideration was given to providing space for an on-board helicopter for certain missions (e.g., sea ice profiling) by placement of a portable landing pad over the tops of the modules. The idea was discarded because the helicopter and pad would restrict the operator's forward vision. However, if a forward control cab is built into the craft at a later date this concept should be reconsidered.

ACV Loading Considerations

The ACV is sensitive to center of gravity location in reference to the center of pressure. These center of gravity limits have been explored in model tests and with the actual vehicle. These tests have shown that an integral center of gravity trimming capability is required to maintain center of gravity limits for most loading cases.

The Voyageur craft is therefore provided with two fuel tanks at the forward end of the craft and one at the rear. Fuel can be transferred between these tanks to trim the vehicle laterally as well as fore and aft. Loading procedures will be established to minimize the fuel ballast requirement. Fuel in the ballast system can be transferred to the main fuel system if necessary.

TABLE IV

SCIENTIFIC LABORATORY CONFIGURATION WEIGHT SUMMARY

Item	Weight (lbs)
Module A (kitchen/diner)	3,800
Module B (sleeper/8-man)	3,530
Module C (washroom/generator)	3,425
Module D (oceanographic laboratory)	3,170
Module E (general laboratory)	2,950
Module F (data/communication center)	2,000
Total	18,875
Ancillary Equipment	
Winch	4,000
Generator	2,040
Auxiliary power unit	1,000
Communication equipment	500
Survival, handling equipment	500
Total	8,040
Total (laboratory and equipment)	26,915

Ancillary Equipment

Radio communication, navigation aids, and safety equipment are not offered as standard items, nor are they included in the basic cost of Voyageur #001 or #003.

The following equipment is considered essential for efficient and safe operation of the ACV:

1. Auxiliary power unit.
2. Navigation system.
3. Radar.
4. Communication equipment.
5. Gyrocompass.
6. Fire prevention equipment.
7. Ice and snow removal handtools.
8. Hand-carried air heaters.
9. ACV lift jacks.
10. Vehicle emergency equipment.
11. Searchlight.
12. Survival equipment.

1. Auxiliary Power Unit (APU). After observing the SK-5 tests at Fort Greely, Alaska (March 1972) and upon the recommendation of Mr. William Lyon, Technical Representative, Bell Aerospace with the test program, it is strongly recommended that an APU be with the vehicle when operating in cold weather regions to lessen battery drain when starting engines or testing navigation and communication equipment. This unit can be mounted aft of the data/communication module.

2. Navigation System. Navigational gear should comprise the following:

ADF (direction finder).
Beacon (Sarah high power unit for SAR).
Inertial (general).
NAVSAT receiver (transit satellite positioning).

3. Radar. The U.S. Coast Guard SK-5 ACVs are using a model LN66 navigation radar built by Karr Electronics. This particular model has proved highly successful and has good resolution on short ranges. This model has been certified by the U.S. Navy as a Class IV radar for all large ships. The approximate cost of the unit including a 5-foot antenna is $5,000. (See Appendix B.)

4. Communications. The communication equipment should consist of:

HF Radio: Point to point (vehicle to Barrow NARL) Collins KWM2-A (RT718/FRC93) transceiver (3 to 30 MHz) or equivalent.

VHF Radio: Collins Radio Model 618M-2 (118-152 MHz), 30 watts nominal.

ADF: Collins Radio Model ARN 83 (190-1750 kHz).

Beacon: VHF rescue (243 MHz).

Intercomm: Kaar PB Monitor (Radio) and ICS ($1,500).

Bullhorn: Mounted external to operator's cabin for communicating with icework crews and site scientists ($200).

5. Gyrocompass. A standard current naval model gyrocompass is recommended (government furnished).

6. Fire Prevention: In addition to the fire detection and extinguishing equipment provided by the manufacturer for the engine and operator compartments, further equipment is required for the modules. Suitable fire extinguishers have been developed by the Naval Arctic Research Laboratory for use at temperatures to -65° F. Dry chemical fire extinguishers such as the Ansul Co. "Purple K" are in use in polar camps. It is recommended that each module be equipped with at least two extinguishers and that fire fighting procedures be posted in each module. Also, all personnel should be familiarized with the system and procedures prior to starting a mission.

7. Ice and Snow Removal Handtools. During ACV operations in the Arctic, ice adhesion to the vehicle may at times be a problem. Freezing of water spray on the skirts and superstructure, freeze-down of the vehicle while parked, and icing of engine intakes and ducts may constitute serious operational hazards. Rubber mallets have been found suitable for removing relatively thin ice from skirts and the superstructure. Ice chisels, picks, and axes would be required for removing large amounts of ice and hard snow and for freeing frozen-down skirts. Shovels will be required for snow removal. These tools should be carried in permanent racks on board the vehicle.

8. Hand-carried Heaters. Portable kerosene or propane heaters as well as small electric heat guns (in the 1,000-watt range) have been used effectively in the Arctic for localized repair operations, and it is recommended that one of these heaters be carried.

9. ACV Lift Jacks. To facilitate inspection of the underside of the craft in remote areas, a system of jacking must be employed. The manufacturer has suggested a system using air bags and scissor jacks. This method requires the placing of four air bags under the craft at positions adjacent to

the landing pads. Air is applied by bleed-off from one of the main engines to the bags, thereby raising the craft approximately 2 feet. Placement of the scissor jacks at the landing pad points will enable the craft to be jacked up another 2 feet. At this point the jacks are locked in position, after which personnel can inspect the underside of the craft. The weight of this system is estimated to be 1,000 pounds.

Another system considered the use of extension hydraulic jacks attached to the bow and stern. This method would require the vehicle to remain on-cushion while jacks are placed in position. When off-cushion the vehicle would rest on either forward or aft landing pads depending on which end was lifted. If further lift is required, the jacks may be extended by applying air or hydraulic pump to them. This system would be lighter in weight than the air bag system and is being considered by the manufacturer.

10. Vehicle Emergency Equipment. A recommended item for self-recovery operations in situations such as loss of cushion due to terrain irregularities, hang up on ice ridges, etc., is a winching system that includes anchoring devices suitable in ice and frozen ground. A portable, self-contained cathead winch is considered most desirable. In addition to this equipment, there should be a towing bridle and line.

11. Searchlight. A lightweight, powerful searchlight will provide increased safety for night and low-level-light operations and will aid in the identification of radar "blips." The light would be remotely controlled from the cabin in both focusing and positioning. A Spectrolab Night Sun searchlight (25,000 lumens) was evaluated by the U.S. Coast Guard (San Francisco Evaluation Unit) and proved highly effective (Ref. C-4-3). This is recommended for installation.

12. Survival Equipment. When operating away from the base area, survival equipment should be carried aboard the vehicle. The equipment should include sleeping bags, tent, food, stove, flares, emergency radio, and homing beacon. Also, the equipment should be packed in floatable containers which can be readily jettisoned in the event of a disabling accident.

Base Support Requirements

To operate and maintain the Voyageur will require the facilities and equipment listed. The starred (*) items are in NARL's inventory and would not require purchasing.

1. Hangar.*
2. Ramp and parking areas.*
3. Portable heater.*

4. Air compressor.*

5. Jack stands.*

6. Travelift crane.

7. Single-point sling.

8. Bulk fuel storage.

9. Associated electrical, mechanical and electronic workshops.*

10. Portable shelter.

1. Hangar. Due to the nature of the vehicle, it is desirable that hangar space be allocated for parking and maintenance. The present hangars at NARL have steel matting over gravel as a floor and during the ARPA/NSRDC SK-5 tests of 1971, a plywood floor was laid on the matting in the area used by the craft. The Voyageur would require a space allocation of at least 7,800 square feet. It is recommended that a 4-foot-high sectional barrier enclose this area to prevent dust and small objects from being blown onto other vehicles or aircraft parked in the hangar. This would require 270 sheets of plywood; 244 for floor and 26 for wind barrier.

An overhead crane in the hangar with sufficient capability to lift an engine or propeller is desirable. Maintenance workshops and parts storage should be located close by.

Procedures would have to be developed for moving the vehicle in and out of the hangar area. The procedure used by Bell at Toronto with the Voyageur is to put the vehicle on-cushion with propellers set at zero pitch. Then it is pushed or pulled into the parking area in the hangar by hand or with the aid of a small aircraft towing vehicle. With the wind barrier in position, no damage occurs to other aircraft parked in the hangar.

2. Ramp and Parking Areas. The vehicle may be parked on the apron area during the summer months and would require 2,500 square feet. Procedures will have to be developed for movement of the vehicle on the apron parking and ramp areas.

3. Portable Heaters. A standard 400,000-Btu portable heater will be required for preheating engines for cold starts and for supplying heat to a collapsible shelter when servicing the vehicle outside the hangar area. Federal Stock Number FSN 4520-720-0715 is recommended (current U.S. price is $2,088).

4. Air Compressor. A system to support the operation of several tools is essential in the hangar, since most repairs, whether on the body structure or the skirts, make use of air-driven tools and rivets. A portable system to support limited work on the parking apron and away from the base is desirable.

5. Jack Stands. These are required as a fail-safe system for working under the craft. In emergency situations, bulk lumber and empty 55-gallon drums will suffice.

6. Travelift Crane. A crane capable of lifting 36,000 pounds is required for lifting the vehicle for underside inspection and skirt repairs, for moving the vehicle from hangar to ramp when necessary, for loading and unloading modules, and for lifting the engine or propellers. The Travelift Crane is recommended. The U.S. Coast Guard has used this machine with good results at its Station ACV facility in support of the SK-5 vehicle.

There are some disadvantages to such a large vehicle in that it requires space to maneuver and generates its own maintenance requirements. The manufacturer's model number 500A1 is quoted by Drott Manufacturing Company at $78,500, but this price does not include arctic conditioning. The vehicle can move a unit 70 feet long by 32 feet wide by 18 feet high to a height of 6 feet.

7. Single-point Sling. Two single-point slings will be required to lift the craft in emergencies, but they can be fabricated at NARL. They can also serve as a towing bridle when required.

8. Bulk Fuel Storage. It is understood that presently there are no bulk capacity areas for JP4/5 fuel. Estimates of fuel requirements for the Voyageur craft for 1 year of operation is 480,000 gallons (2,000 hours minimum use). It is recommended that a pillow tank farm of 250,000 gallons be established (5 at 50,000 gallon capacity) to provide a minimum 6-month supply. Estimated cost of tanks, pump, and accessory hoses, etc., is $32,000.

9. Workshops. The maintenance, electrical, mechanical, and electronic workshops at NARL will be adequate to support the Voyageur. There will be a requirement for storage of spare parts and accessories.

10. Portable Shelter. A portable lightweight shelter made of neoprene-coated nylon which can be easily erected over an engine unit or other part of the vehicle for repairs under severe weather conditions is desirable. Heating of the shelter can be provided by an external Herman Nelson heater or by bleed-off from one of the two cabin heaters.

ACV Shipment and Reassembly at Point Barrow

The Voyageur can be broken down into 12 units (Figure 6 and Table V) for shipment to the user. Shipment of these units can be made by flatbed truck or cargo aircraft.

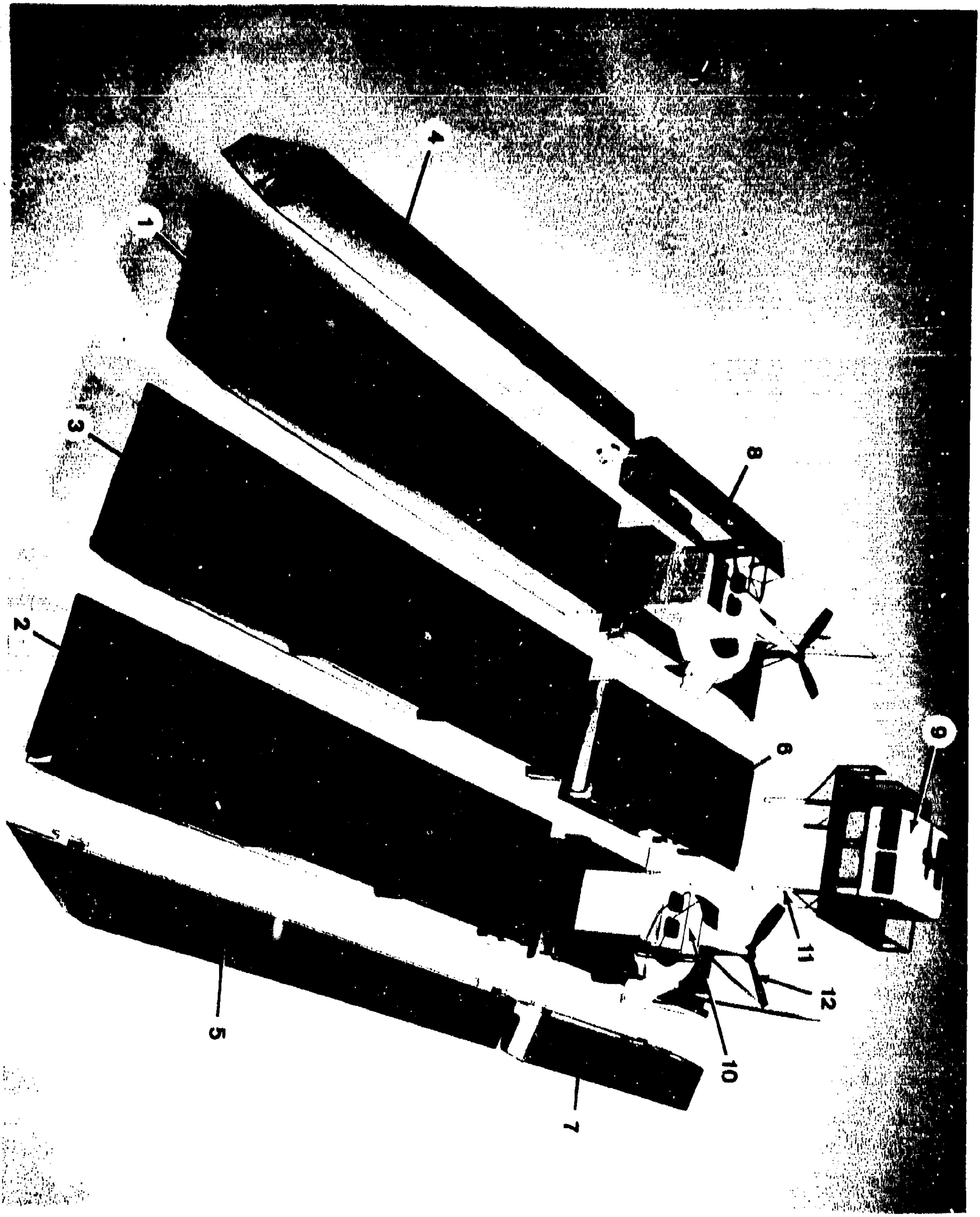


Figure 6. Voyageur Breakdown for Shipment

TABLE V

VOYAGEUR BREAKDOWN FOR SHIPPING

Components (See Figure 9)	Length (ft)	Width (ft)	Depth	Weight (lb)
1. Stbd fwd box with pad	40	8-1/2	3' 11-1/2"	4,000
Stbd fwd box w/o pad	40	8-1/2	3' 1-1/2"	4,000
2. Port fwd box with pad	40	8-1/2	3' 11-1/2"	4,000
Port fwd box w/o pad	40	8-1/2	3' 1-1/2"	4,000
3. Center fwd box	40	8-1/2	3' 1-1/2"	3,650
4. Stbd fwd side box	40	3-1/2	3' 1-1/2"	900
5. Port fwd side box	40	3-1/2	3' 1-1/2"	900
6. Center aft box	19-1/2	8-1/2	3' 1-1/2"	1,650
7. Port aft box	19-1/2	3-1/2	3'1-1/2"	510
8. Stbd aft box	19-1/2	3-1/2	3' 1-1/2"	510
9. Control cabin	8	9	5' 6-1/2"	2,500
10. Power module, less pad, propeller, air trunk, fin (two)	19-1/2	8-1/2	8'10"	4,500 each
Skirts and trunks	Removed and placed in canvas sacks			3,500
11. Cabin support truss	4" x 4" x 7' girders			250
12. Propellers	9	9	12"	680 each

In considering the delivery of a Voyageur to Point Barrow, the simplest method is by air. Utilizing Military Airlift Command would require three full loads for a C-124 Globemaster or four loads for the C-130 Hercules.

Support equipment required at Barrow prior to delivery would be:

Two 15-ton cranes.

One forklift.

Four single-point slings.

A supply of 2x4 lumber.

Sixty empty fuel drums.

It is recommended that the entire floor area of the USAF hangar be used as an assembly area for the vehicle.

To accomplish breakdown, shipment, and reassembly will take:

Breakdown and loading	300 man-hours (40 for loading)
Unloading and reassembly	450 man-hours (32 for unloading)
Check out of all systems	10 man-hours

In terms of manpower, this would require 10 men for 3 days to disassemble and load, and 8 men for 7 days to unload, reassemble, and place into operation. This would include one technical representative from the manufacturer to oversee the operations. Costs quoted by the manufacturer for the operation are $46,000.

Operation and Maintenance

The normal crew complement for Voyageur #001, based on the vehicle manufacturer's recommendations, includes an operator, a navigator, and a mechanic/handler. It is assumed that the vehicle operator will undergo formal training at the factory and be checked out by experienced Bell operators on the Voyageur #001 at Point Barrow. Through on-the-job training, the navigator will be oriented and checked out by the craft operator for taking over during emergencies or periods when the commander of the vehicle is not available.

All crew members will be trained in preventive maintenance and will handle these requirements routinely as prescribed by the manufacturer. The mechanic/handler will be qualified to handle routine engine maintenance procedures, and hydraulic and mechanical defects, particularly those involving skirt repairs.

A major engine overhaul will be handled by the engine supplier. Engine maintenance associated with normal field operations will be assigned to jet engine mechanics available through the base support services at Point Barrow.

Due to the complexity of the craft and the unavailability of experienced personnel to handle operation and maintenance requirements, it is recommended that these services be procured on an annual contracted basis.

Except for the NARL resupply lighterage mission, all other mission profiles analyzed in this study can be handled by a single 3-man crew. In the case of the lighterage mission, the operator position will be rotated among the 3-man crew to meet the 24-hour operational requirements for this mission. It is not essential that the navigator's role be fulfilled by a separate crew member for this mission. Additional crew spots will be filled by available local area personnel.

It is recommended that arrangements be made with Bell Aerospace to provide annual factory refresher training for operation and maintenance personnel.

User Mission Requirements

Thirty-five user questionnaires (Appendix B) were distributed to principal investigators, key project personnel, and individuals actively engaged in or associated with scientific projects in the Arctic Basin. Responses have been received from 13 contacts (36 percent). A summary of the data on future mission requirements is shown in Table VI.

The future mission requirements reported and preferences for other applications of the air cushion vehicle are classified as follows:

1. Botton sampling.
2. Auto sensor data buoy deployment and MIZ investigations.
3. Point Barrow ship/barge cargo lighterage.
4. AIDJEX satellite camp cargo and personnel ferry operations.
5. Bering Sea oceanographics.
6. Sea ice profiling.
7. NARL field station resupply.

Other missions where the ACV could be employed effectively but have not been analyzed include Ice Island (T-3) resupply, coastal fast ice investigations, geophysical explorations and emergency rescue. A brief description of each of these missions if given in Section IV, with an outline of the most practical way of implementing this mission using an ACV.

TABLE VI

SURVEY SUMMARY OF MISSION REQUIREMENTS

Contact	ACV Missions	Average Range or Duration	Multi-mission Capability	Manpower
Schindler NARL	1. Scientific 2. Supply (ice station) 3. Mobile lab 4. SAR 5. Field station supply	300 miles	Yes	
Haugen U. of Wash.	1. Oceanography 2. Acoustics (MIZ) 3. Auto sensor deployment	1-21 days	Yes	3
Wentnick U. of Ak.	1. Offshore Ice Studies		No	
Buck GM Delco	1. Acoustic prop. 2. Auto station deployment 3. Oceanographic tests	1-10 days		6-8
Wittmann ONR-Polar	1. Ice dynamics 2. Ice oceanography 3. Ice acoustical 4. Ground truth 5. Buoy deployment 6. Submarine SAR 7. Bathymetric	1-3 days 1-5 days 1-14 days 1-3 days 2 days	Yes	4-5
Roots PCSP (Canada)	No planned missions from NARL			
Gagnon CRREL	1. Logistic supply			
Brewer St. of Ak.	1. Bering Sea oceanography			
Allen U. of Ak.	1. Botton sampling			
Weeks CRREL	1. Ice dynamics 2. Logistic support			
Liston CRREL	1. Sea ice research 2. Logistics transport			
Stateman	1. Data ollection (general)			
Sater	1. Oceanography 2. Meteorology			

User inputs from the requirements survey indicate that the planned experiments can generally be conducted within a 300-mile radius of NARL. For the type of terrain the ACV must traverse, it has been assumed that a safe cruising speed for the craft is 30 miles per hour. At this speed, the vehicle has adequate fuel capacity to support a 10-hour running mission (#001 and #003 consume 200 gallons per hour) with a limited fuel reserve for emergencies.

Assumptions

For each mission profile analyzed, the following conditions hold:

1. The ACV will normally achieve all missions within an area no further than 150 nautical miles from Point Barrow.

2. For missions requiring fuel loading beyond the craft's normal capacity, either facilities will be provided on board to accommodate the additional fuel requirement or logistic fuel support will be provided by NARL at convenient fuel cache sites or by airlifting and refueling the ACV on station. Procedures for accomplishing the latter have not been thoroughly investigated; however, it is currently felt that refueling during a mission can be performed within the present state of technology.

3. The full laboratory configuration of modules and ancillary equipment will be removed when the vehicle is assigned to cargo handling missions so that the maximum available cargo space and payload weight can be allocated for the task.

4. All assigned missions will carry a full crew (one operator, one navigator, and one mechanic/handler).

5. HF radio communication can be maintained between the ACV and NARL with no anticipated difficulty. Alternate voice and/or data circuits can be established via ground to aircraft radio links.

6. Accurate vehicle position can be furnished by a transit terminal working through the Navy Navigation Satellite System.

7. Available arctic transportation presently used to support many of the missions considered in this study is indicated in Table VII. The operational limitations and influences of seasonal variations are illustrated in Figure 7 . Aircraft are utilized extensively throughout the arctic for handling cargo, for transporting personnel, and in some instances serving as a temporary scientific field laboratory. Performance characteristics of the more commonly used aircraft are cited in Table VIII. Where appropriate, these vehicles will be used to compare the cost effectiveness of the ACV for the applicable mission.

TABLE VII

INVENTORY OF ARCTIC TRANSPORTATION

Existing Method	Key Limitations
Marine	
Shallow draft ships and barges Coast Guard Icebreaker Submarine Ice-strengthened research ship	Ice concentration in ship channels and Arctic Ocean areas Icebreaker and submarine availability
Motor/Railroad	
Balloon tire vehicles (Rolligan) Tracked vehicles (Track Master) Amphibious craft (Dukys)	Travel over tundra difficult during summer season
Alaskan Railroad	Limited routes (railroad)
Aircraft	
C-130 C-47 Twin-Otter Buffalo Skycrane Helicopter (light)	Lack of instrumented, hard surfaced runways Bad flying weather
Other	
Dog sled Skimobiles	Limited cargo and personnel payloads

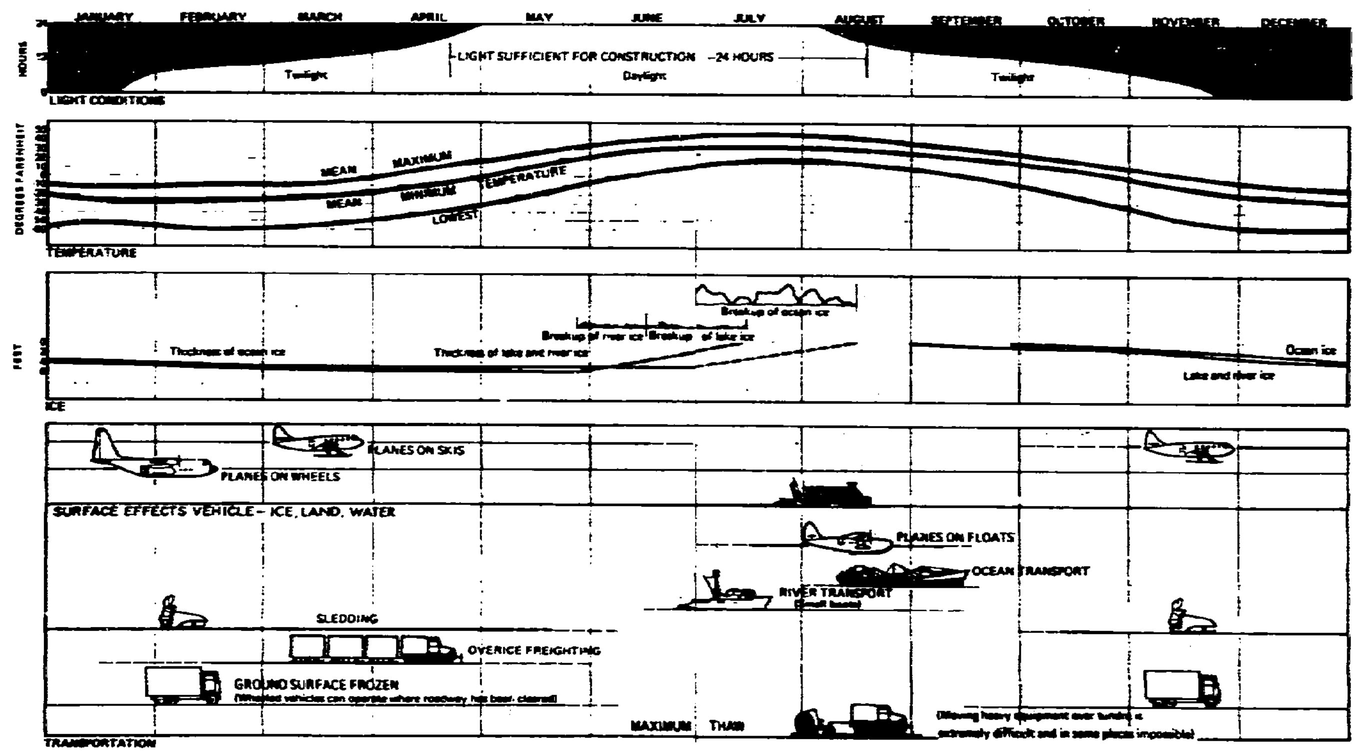


Figure 7. *Diagrammatic representation of seasonal variations and their influence on operations in the Arctic.*

TABLE VIII

ARCTIC TRANSPORT
VEHICLE CHARACTERISTICS

Type	Available Payload (lb)	Fuel Used/Hr (Full Payload) (gal/hr)	Average Speed (Full Payload) (mph)	Tank Capacity (gal)
C-130	40,000	675	310	1,840
R4D Cessna	4,700	60	130	840
Twin-Otter	3,500	70	190	616
Bell Copter (205)	3,870	80	125	405
Bell Jet Ranger	1,360	25	130	76

Source Data:

MFGR Spec Sheets
AIDJEX Planning Office
ONR

8. The planning of safe routes for the ACV missions is contingent on the ability of the vehicle to override ice pressure ridges up to 4 feet in height or to divert the ACV to unobstructed paths when ridging exceeds 4 feet. Table IX identifies the ridge zones and their approximate locations within the planned operating radius (150 nautical miles from NARL). Zone II, which contains ridges up to 15 feet, presents the most serious challenge for directly accessing remote sites on the Arctic Ocean. Birdseye photographs of tracks along the axis of main ridges in Zone II show concentrations of high ridges (over 4 feet) with very few openings for ACV passage around the Point at Barrow. On either side of the Point, for distances of 5 to 7 miles, there are few suitable access paths through Zone II (Figure 8.). In planning routes to stations on the Arctic Ocean, paths must be chosen that reroute the ACV inland for approximately 10 miles before changing the heading to due North. At this point, Birdseye photographs indicate relatively clear paths or openings at the rate of one per mile through the near shore ridge zone. The ACV will travel at considerably lower speeds (5 to 7 knots) across this route. Ten percent has been added to the total mission mileage calculation to compensate for ACV rerouting through Zone II.

Average height of ice ridges beyond Zone II appears to be less than 4 feet. Path rerouting out on the Arctic Ocean (beyond 25 miles), though necessary, will be minimum.

TABLE IX

ICE ZONES
(COAST TO 150 MILES OFF POINT BARROW)

Distance	Zone	Ice Characteristics
>70 miles	V	Polar pack Latitude approximately 75° North Multiyear ice MIZ
30 miles	IV	Heavily ridged 4-foot ridges average First year and multiyear ice
20 miles	III	Flaw zone Quasi-permanent leads
2 miles	II	Ridged 7 to 10 foot ridges average Open water in summer
15 miles	I	Fast ice Open water in summer

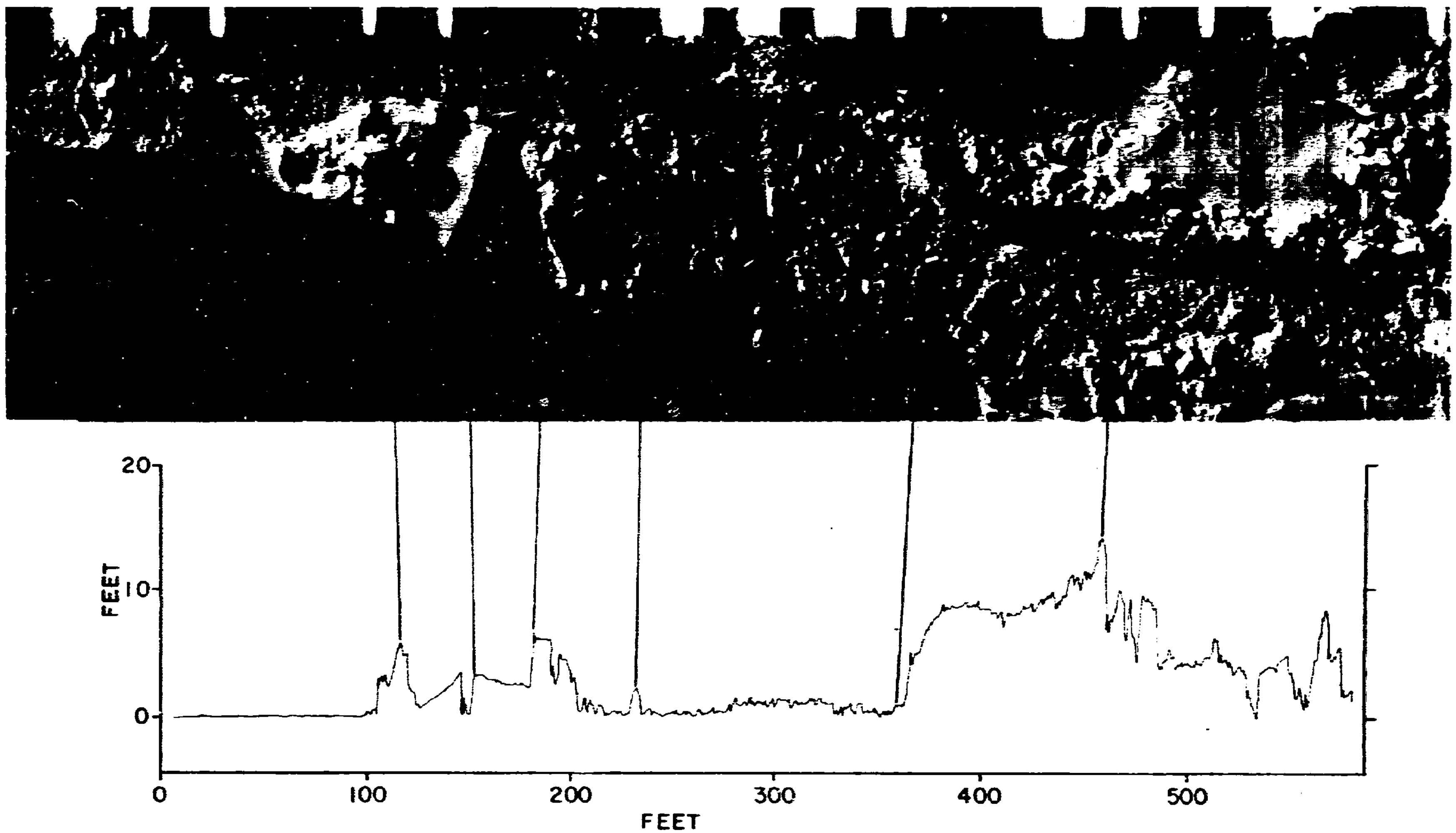


Figure 8. Ice Ridges Near Point Barrow (5 Miles Offshore)

SECTION IV

MISSION PROFILES

Bottom Sampling

When equipped as a scientific laboratory, the ACV will operate between Fort Wainwright and Point Barrow, a distance of approximately 85 miles, stopping at 5-mile intervals enroute to acquire bottom samples (either core or plankton). The entire mission will consist of 17 drops. Each sampling operation is assumed to take 20 minutes in open water. This includes cast and retrieval of the sample. Where sea ice prevails (winter operations), to obtain a sample is estimated to take 45 minutes, including the boring of a hole through 15-foot-thick ice.

Typical mission routing involves heading the craft southwest from NARL along the shore for about 10 miles to avoid ice ridges (Zone II) and then proceeding north from this point to a location 15 miles offshore which is the start of a stright line sampling track (17 drops) as far south as Fort Wainwright (Figure 9). The total ACV route mileage is estimated to be 200 miles round trip. Based on an ACV cruising speed of 30 miles per hour, the total time to complete the sampling mission is 12.7 hours during breakup season and 22.9 hours under sea ice conditions (winter operations). This higher figure allows for rerouting and time consumed in drilling ice holes. Total personnel aboard the ACV is five (two scientists and the 3-man crew).

Configuration of laboratory space and equipment provides for approximately 4 tons of unused payload, which is more than adequate to cover the weight of extra fuel or any specialized instruments assigned to the mission. (Table X is a data sheet for this mission.)

Auto Data Buoy Deployment and MIZ Investigations

The purpose of this mission is to deploy arctic data buoys off the northern coast of Alaska in conjunction with an oceanographic mission * in the Marginal Ice Zone (MIZ) which, for our purposes, is assumed to be located approximately 75 to 100 miles offshore (Figure 10). The data buoy is a University of Washington APL automatic meteorological station designed for NOAA.** Four buoys 100 miles apart will be deployed off the north coast from Icy Cape, Point Barrow, Point McIntyre, and Barter Island. These unmanned stations would provide macroscale meteorological data for arctic weather forecasting. The buoys operate unattended and have a self-contained energy source to provide power during its 1-year operational life.

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* Air Cushion Vehicle Evaluation Report, U.S. Coast Guard, ACV-EV3960-01 January-August, 1971 (Annex F).

** Experimental Arctic Data Buoy, Interim report APL-UW-7207, NOAA Funding for APL, University of Washington, February 1972.

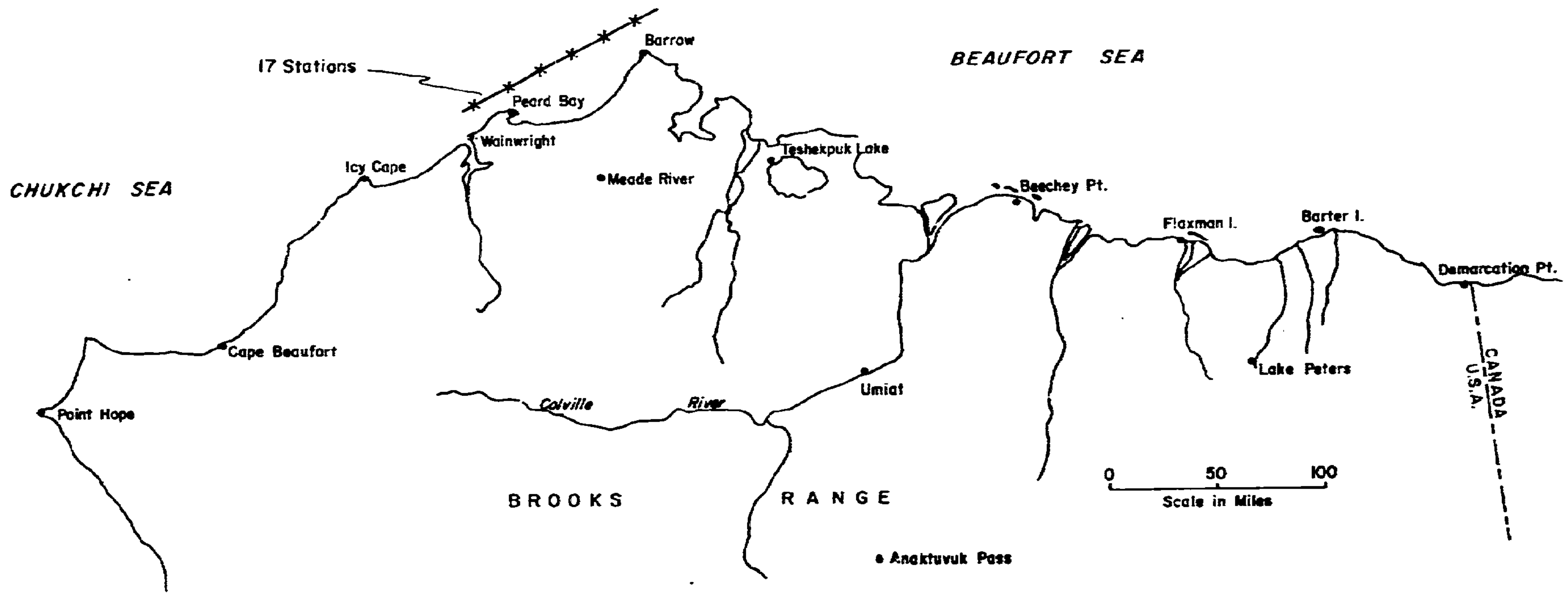

Figure 9. Bottom Sampling Mission

TABLE X

BOTTOM SAMPLING MISSION DATA SHEET

Route distance (round trip)		200 miles
Open water		200 miles
Sea ice		250 miles
Fuel consumption		
Running at 200 gal/hr		
Open water		1,332 gals.
Sea ice		1,600 gals
Idle at 60 gal/hr (5 min/stop)		85 glas
Mission time		
Open water (breakup season)		15 hours
Sea ice (winter)		25 hours
ACV running time		
Open water		6.5 hours
Sea ice		8.0 hours
Station stops (5-mile intervals)		17
Open water		30 min
Sea ice		60 min
Refueling stops		None
	#001	#003
Available payload:	37,748 lb*	36,112 lb*
Full laboratory configuration	26,915	26,915
Passenger load (5 men at 280 lb)	1,400	1,400
Total committed weight	28,315	28,315
Spare payload	9,469	7,797

*Fuel tanks full

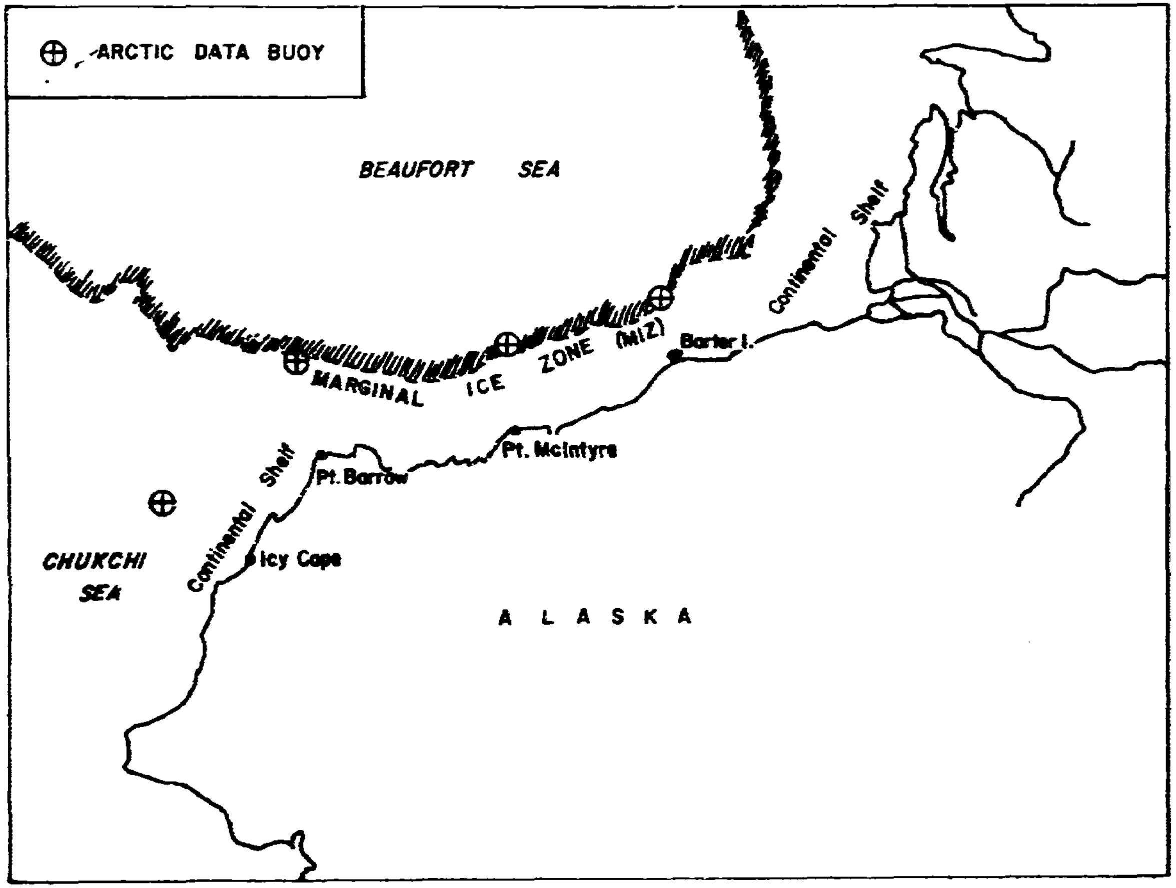

Figure 10. Arctic Data Buoy Deployment and MIZ Investigations

Concurrent with the implanting of each buoy,. oceanographic experiments are conducted and data collected in the MIZ; at least 10 recording sites (one per mile) are established over a 2.5-hour period.

The MIZ investigation team will comprise one scientist and two technical assistants. The regularly assigned ACV crew will assist an engineer assigned to install and check out the data buoys. Total mission personnel complement is seven. Since the range of this mission exeeds the normal fuel capacity of the ACV, refueling caches (JP4 or JP5) are required at Icy Cape, Point McIntyre, and Barter Island.

The entire mission is scheduled to be achieved in four phases.

1. Phase I (1 day). The ACV will depart from Point Barrow to the MIZ area (approximately 75 miles due north of Point Barrow). It will take about 3.25 hours by ACV to reach the buoy positioning site Another 2 hours will be required for two men to implant and test the data buoy.* While this operation is underway, MIZ data will be acquired for a track distance of 10 miles, consuming another 2.5 hours Operating the ACV at an average of 35 miles per hour on the return leg will place the ACV at home base (NARL) in 3 hours. Total operational time required for Phase I is 10.75 to 11 hours.

2. Phase II (2 days). This phase of the mission entails the deployment of a data buoy about 75 miles north of Icy Cape, with MIZ investigations in the local area and return to Icy Cape. Total operating time is 16.5 hours. It is based on the following:

1	Run from Barrow to Icy Cape (120 miles)	4.0 hours
2.	Refuel at Icy Cape	0.5 hour
3	Head north to MIZ and data buoy site (75 miles)*	2.5 hours
4.	Deployment of buoy and MIZ tests	4.5 hours
5.	Return to Point Barrow (150 miles)	5.0 hours
Total		16.5 hours

* Overnight stop

3. Phase III (2.5 days). The routine of this trip is similar to Phases I and II except that the destination is Point McIntyre. The site is approximately 185 miles from Point Barrow. Running time by ACV is about 6 hours (30 mph average). From Point McIntyre to the operation site is another 75 miles (2 hours running time). The work performed at the site is similar to that mentioned in Phases I and II and will take 4.5 hours. The return vehicle running time to Point McIntyre is 2 hours. The temporary home base for Phase III is Barter Island (about 3.5 hours running time). Eighteen hours of operating time is consumed in Phase III, requiring about 2.5 days.

*Op. cit., U.S Coast Guard.

4. Phase IV (2 days). From Barter Island, the MIZ area and data buoy deployment site is 75 miles north (2 hours travel time). MIZ data collection and buoy deployment time averages 4.5 hours. The return trip to Barter Island can be achieved in about 2 hours. The total mission time consumed thus far is 8.5 hours. It is planned that the ACV will lay over at Barter Island and will refuel for the 300-mile journey back to Point Barrow (10 hours running time). Actual operating time consumed by this phase of the mission is 18.5 hours.

Additional payload required for this journey consists of:

Toboggan (1)	1,000 lb
Data buoys (4 at 500 lb each)	2,000 lb
Sled (1)	120 lb
STD (1)	1,000 lb
Housing and messing equipment	200 lb
Food supplies	200 lb
Ice auger	200 lb
Extra diesel fuel (6 drums)	2,200 lb
Total weight	6,920 lb

Counting this additional weight, the uncommitted payload reserve is about 1,500 pounds. (Table XI is a data sheet for this mission.)

Point Barrow Ship/Barge Cargo Lighterage

Bulk cargo shipments (oil, food, etc.) and heavy equipment and construction materials are normally shipped via ocean-going freighters or tug-towed barge trains from Seattle to Point Barrow annually.* This operation is conducted during the breakup period (July and August) when offshore ice conditions are minimal and lightering operations to shore can be readily achieved by shallow towed barges or small lighterage craft. In either instance, due to the offshore icing conditions, the mother ship must lay at anchor as far as 6 to 8 miles offshore.

The dry tonnage transferred to Barrow in 1971 was about 2,330 tons* and bulk POL (fuel) 3,815 tons. The capacity of the lightering barge varies from 40 to 50 tons. The unloading operation of dry cargo consists of removing the cargo and the lightering craft from the mother barge, with the lighterage vessel moving the destined cargo to the beach area. There, the cargo is unloaded by local NARL handlers using cranes and forklifts and then delivered to terminals on the base in a round-the-clock operation. The cargo transfer cycle takes from 4 to 5 days.

*Cool Barge/Pacer Alaska -- After Action Report 1971, Alaska Puget United Transportation Company Report, November 15, 1971.

TABLE XI

AUTO DATA BUOY DEPLOYMENT AND MIZ INVESTIGATION MISSION DATA SHEET

Route distance (round trip)		1,000 miles
75 miles offshore; 400-mile track between Icy Cape and Barter Island (4 buoys installed)		
Fuel consumption		9,200 gal
Running at 200 gal/hr		1,080 gal
Idle at 60 gal/hr		
Mission time		7.5 days
ACV running time		46.0 hours
Station stops		
Buoy deployment		8.0 hours
MIZ experiments		10.0 hours
Refueling stops		4
Icy Cape		
Barter Island		
Point Barrow		
Point McIntyre		

	#001	#003
Available payload	37,784 lb*	36,112 lb*
Full lab configuration	26,915	26,915
Passenger load (7 men at 280 lb ea)	1,960	1,960
Total commited weight	28,875	28,875
Spare payload	8,909	7,237

*Fuel tanks full

Although the maximum payload capacity of the flatbed Voyageur #001 is approximately 19 tons (less than half the payload capability of the lightering barge), it is recommended for this mission because it is an all-season transport and can more readily traverse land, ice, and water interfaces without the limitation of the lighterage barge. Also, using the ACV, transfer of cargo at the beach is unnecessary, and the unloaded barge cargo can be delivered directly to the camp distribution point.

With Voyageur (#001) fuel tanks half-filled, the ACV payload can be increased to 22 tons. By ACV, on a round-the-clock schedule, the dry cargo delivered to Barrow can be unloaded in 6.5 days (average 16 trips/day). Under this schedule, two ACV operating crews are required. Assuming that the mission is performed on a more normal schedule (10 hours/day), the unloading task can be accomplished in 13 days with the normal crew.

Since theVoyageur is not basically configured to carry bulk fuel, it cannot compete with tanker barges, and so is not considered for handling this unloading mission. (Table XII is a data sheet for this mission.)

AIDJEX Satellite Camp Cargo and Passenger Ferry Operations

In this mode the ACV is used as basic transportation for supplies and personnel to and from the satellite camps and the main base campsite (Figure 11). This mission can be undertaken on a daily basis or on a weekly schedule from the main camp. It is assumed that the ACV will be assigned for the duration (2 months) of the AIDJEX field program and means will be provided to move the ACV to the main base camp along with other capital equipment during the camp setup phase.

In addition, the ACV can be deployed as an emergency evacuation platform in the event of threatened camp early evacuation due to ice breakup.*

Other tasks that the ACV is equipped to fulfill but which have not been thoroughly investigated are:

1. Deployment of automatic sensor platforms.
2. Ground truth measurements monitoring base.
3. Satellite camp replacement.
4. Search and rescue missions.
5. Base camp to extend the field experimental period.
6. Evacuation base.
7. C-130 base camp cargo transport.

Table XIII is a data sheet for this mission.

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* AIDJEX Main Camp Evacuation, AIDJEX Memorandum 72-9, March 22, 1972

TABLE XII

POINT BARROW SHIP/BARGE CARGO LIGHTERAGE MISSION DATA SHEET

Route distance (round trip) (Barge to terminal points)	10 miles/trip average
Fuel consumption* 24-hour or 10-hour/day operation	16,800 gallons
Mission time	
24-hour operation	6.5 days
10-hour operating day	13.0 days
Available payload (dry cargo weight)	22 tons**

Assumptions

Dry cargo tonnage = 2,300 tons

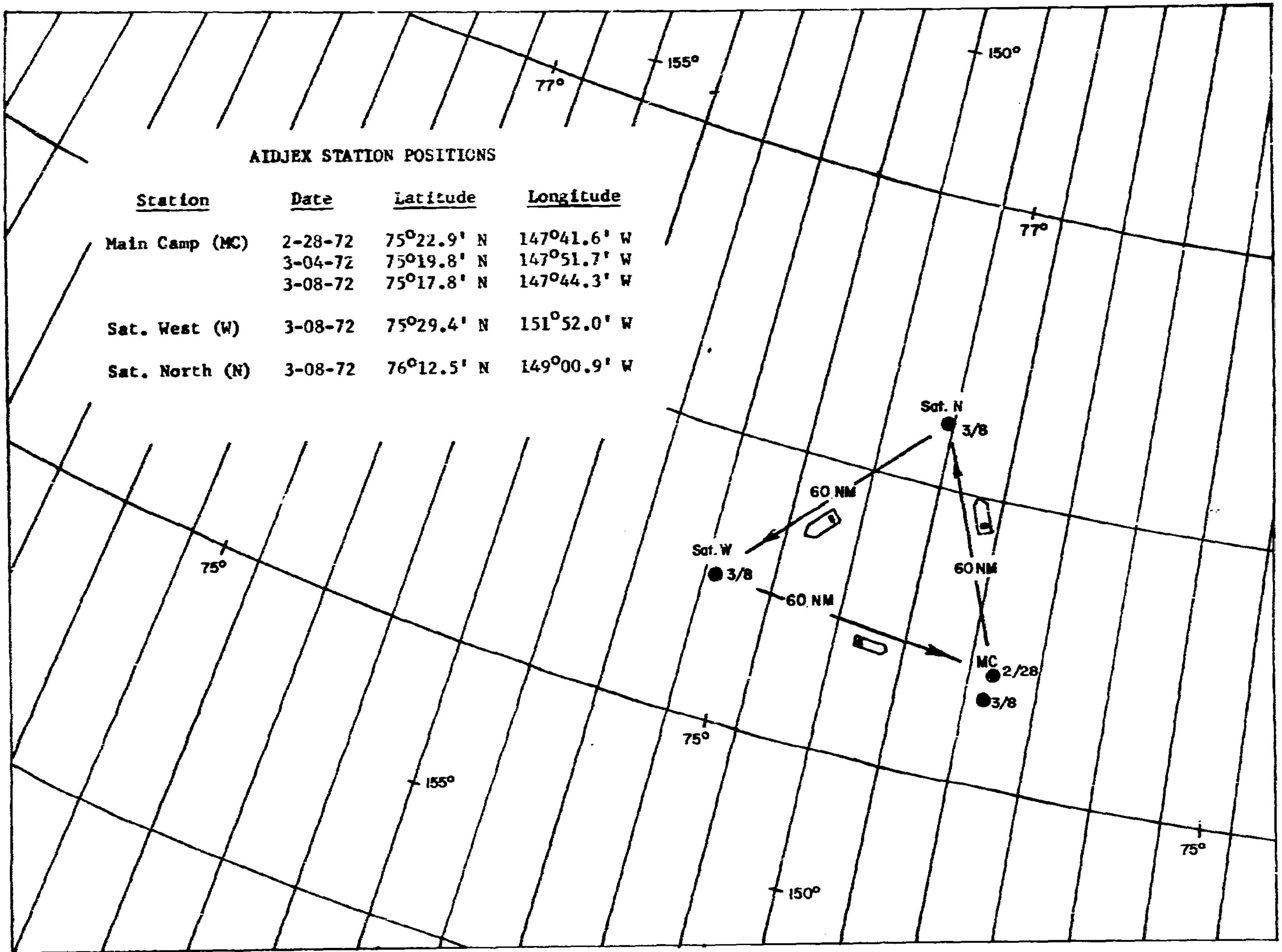
Time elapsed (round trip)

Load	30 min
Unload	30 min
Travel	15 min
Refuel	15 min
Total	90 min = 1.5 hours

*Based on 105 trips to unload total cargo

ACV running time at 200 gal/hr	=	52.5 hours
Idle time at 60 gal/hr	=	105.0 hours

**Fuel tanks at one-half capacity



AIDJEX STATION POSITIONS

Station	Date	Latitude	Longitude
Main Camp (MC)	2-28-72	75°22.9' N	147°41.6' W
	3-04-72	75°19.8' N	147°51.7' W
	3-08-72	75°17.8' N	147°44.3' W
Sat. West (W)	3-08-72	75°29.4' N	151°52.0' W
Sat. North (N)	3-08-72	76°12.5' N	149°00.9' W

Figure 11. AIDJEX Satellite Camp Cargo and Passenger Ferry Operations

TABLE XIII

AIDJEX SATELLITE CAMP CARGO AND
PASSENGER FERRY OPERATION MISSION DATA SHEET

Route distance (round trip)		200 miles
Fuel consumption		
Running at 200 gal/hr		
Idle at 60 gal/hr		90 gallons
Mission time		8 hours
ACV running time		6 hours
Station stops		2
Refueling stops		None
	#001	#003
Available payload	37,784 lb*	36,112 lb*
Miscellaneous weight**	2,000	2,000
Passenger load (3 men at 280 each)	840	840
Total committed weight	2,840	2,840
Net available payload	34,944	33,272

*Fuel tanks full

** Data recording and communications center module aboard

Bering Sea Oceanographics

A long-standing requirement exists for unproven oceanographic data reporting from the Bering Sea area. Realization of this mission has been hampered by lack of a suitable and economical platform from which to acquire the information and by the high cost of logistic support.

Employing an ACV which could be temporarily based at Kotzebue, Wales, Point Hope or Nome, the Voyageur would serve as a mobile laboratory and data acquisition platform and would carry the full laboratory complement of onboard modules recommended in Section III.

The survey area is 450 miles by 300 miles and comprises four ACV track routes. Twenty-eight oceanographic stations will be established (seven per track) and will be spaced approximately 75 miles apart. The initial track line is about 25 miles offshore (Figure 12).

Assuming that at least two stations will be established per day, the entire mission can be accomplished in 15.5 days running continuously (7-day week). Otherwise (5-day week, 10-hour day) the mission would require at least 3 weeks which is not recommended.

At least eight refueling operations are necessary, and it is assumed that the ACV can be refueled on station by airlift or marine transport.

Scientific manpower required to support the mission in addition to the ACV crew (3 men) is estimated at two persons. It is assumed that part of the ACV crew will assist in general handling activities.

Commitment to this mission on a continuing basis seems practical only if more than one ACV is assigned to NARL. (Table XIV is a data sheet for this mission).

Sea ice profiling (topside/bottomside)

The ACV in this application serves as a data collection station and command and control center to coordiante airborne and underwater sea ice profiling activities. The topside profiling platform is assumed to be the Birdseye aircraft or a helicopter equipped to run laser profiles. Underice coutouring could be accomplished by an assigned nuclear submarine or an unmanned submersible (for example, University of Washington's Underwater Arctic Research Submersible, UARS). Due to the relative differences in operating speeds and ranges, it is assumed that the helicopter is paired with the UARS and that the Birdseye flight is coordinated with the manned submarine.

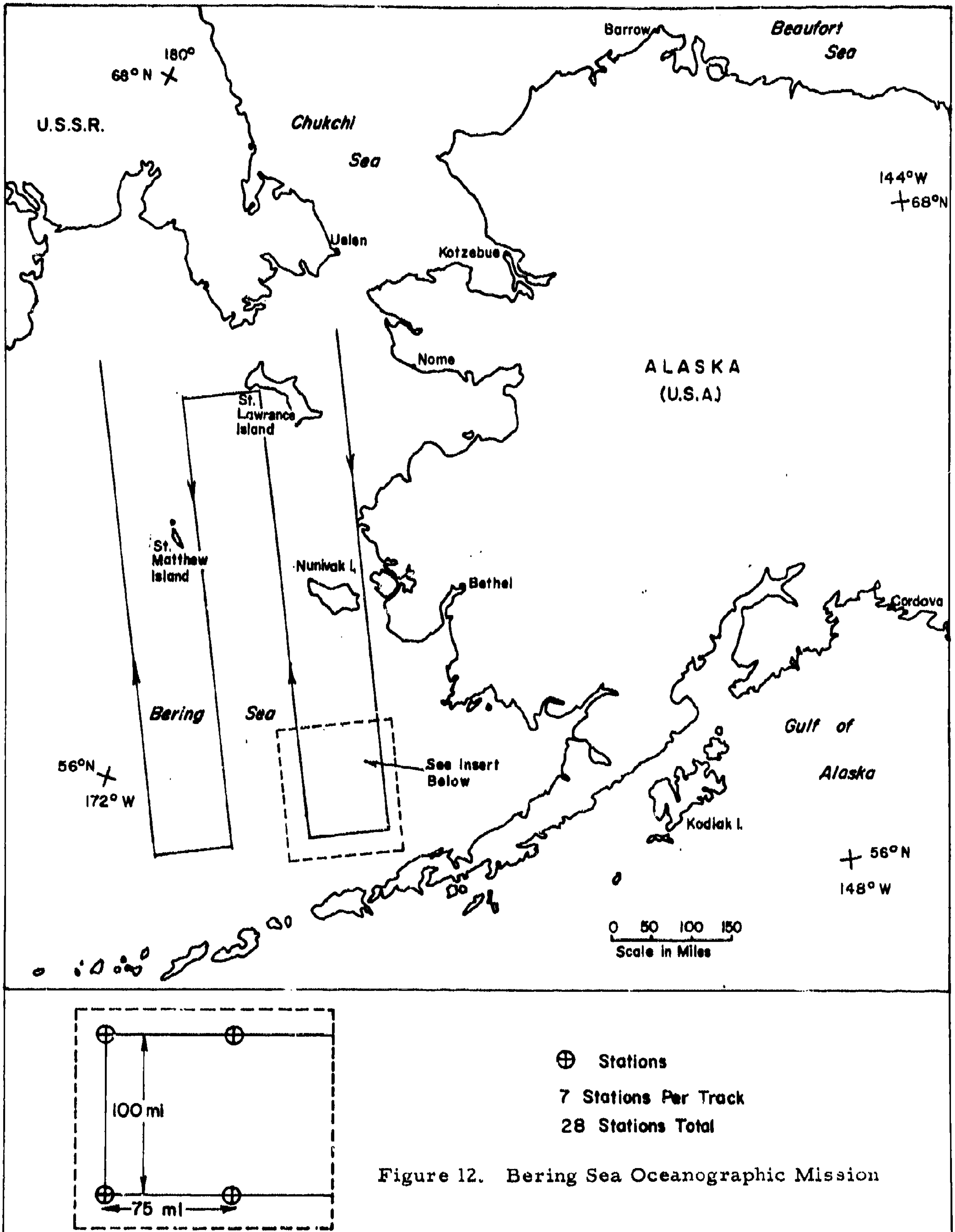


Figure 12. Bering Sea Oceanographic Mission

TABLE XIV

BERING SEA OCEANOGRAPHIC MISSION DATA SHEET

Route distance (round trip)		2,500 miles
Fuel consumption		16,660 gal
Running at 200 gal/hr		1,660 gal
Idle at 60 gal/hr (10% of running)		
Mission time		15.5 days (7-day week)
ACV running time (at 30 mph)		83.3 hours
Station stops		28
Refueling stops		8
	#001	#003
Available payload	37,784 lb*	36,112 lb*
Full laboratory configuration	26,915	26,915
Passenger load (5 men at 280 ea)	1,400	1,400
Diesel fuel (4 drums)	2,000	2,000
Total committed weight	30,315	30,315
Spare payload	7,469	5,797

*Assume on-station refueling at 2-day intervals

A typical mission track is along a radial from NARL (10 to 15 miles offshore) 20 miles to 100 miles long (Figure 13). Dependent upon the extent of area coverage desired, additional radials can be programmed by fanning out of Point Barrow (NARL).

Where a Birdseye flight is coordinated with the nuclear submarine, appropriate voice communication links and data handling channels will be provided aboard the ACV to effectively synchronize the profiling data inputs which at best will be a difficult task. The ACV will move along the planned track profile and serve as an accurate position reference and beacon for the other vehicles. Where the helicopter and UARS submersible are assigned the profiling task, the ACV will serve as the UARS command station as well as the position reference and landing pad for the chopper.

The time required to profile a 100-mile track is governed by the speed of the bottomside profiler platform. Since the UARS runs at 3 knots, it can profile 20 miles in roughly 6.5 hours by a manned submarine for a 100-mile track. Where time is not the important consideration, profiling the sea ice using a helicopter and UARS submersible is desirable due to the accrued economic savings and the availability of the platforms. With an experienced technical staff, it should take about 4 hours to implant the UARS control and homing system and check out the submersible. An allowance of 10 hours to complete the profiling of each 20-mile section of track appears reasonable. Since the helicopter can profile at higher speeds than the submersible, it will be called upon to perform on-station after bottomside profiling has started. The 100-mile track can be profiled in 5 days using the combination ACV, helicopter, and UARS with the ACV returning to NARL on the sixth day.

Using an ACV, Birdseye aircraft, and nuclear submarine, the 100-mile track can be profiled in 1 day. (Table XV is a data sheet for this mission.)

NARL Field Station Resupply

This mission is one of basically hauling cargo and personnel to NARL scientific field sites. Station stops include Wainwright, Meade River, Umiat, Barter Island, and Lake Peters (Figure 14).

For ease of analysis, the mission is divided into three trips routed as follows:

Trip 1 -- Barrow (NARL) to Wainwright to Meade River and return to NARL (130 miles).

Trip 2 -- Barrow to Barter Island to Lake Peters and return to Barrow (755 miles).

Trip 3 -- NARL to Umiat and return (350 miles).

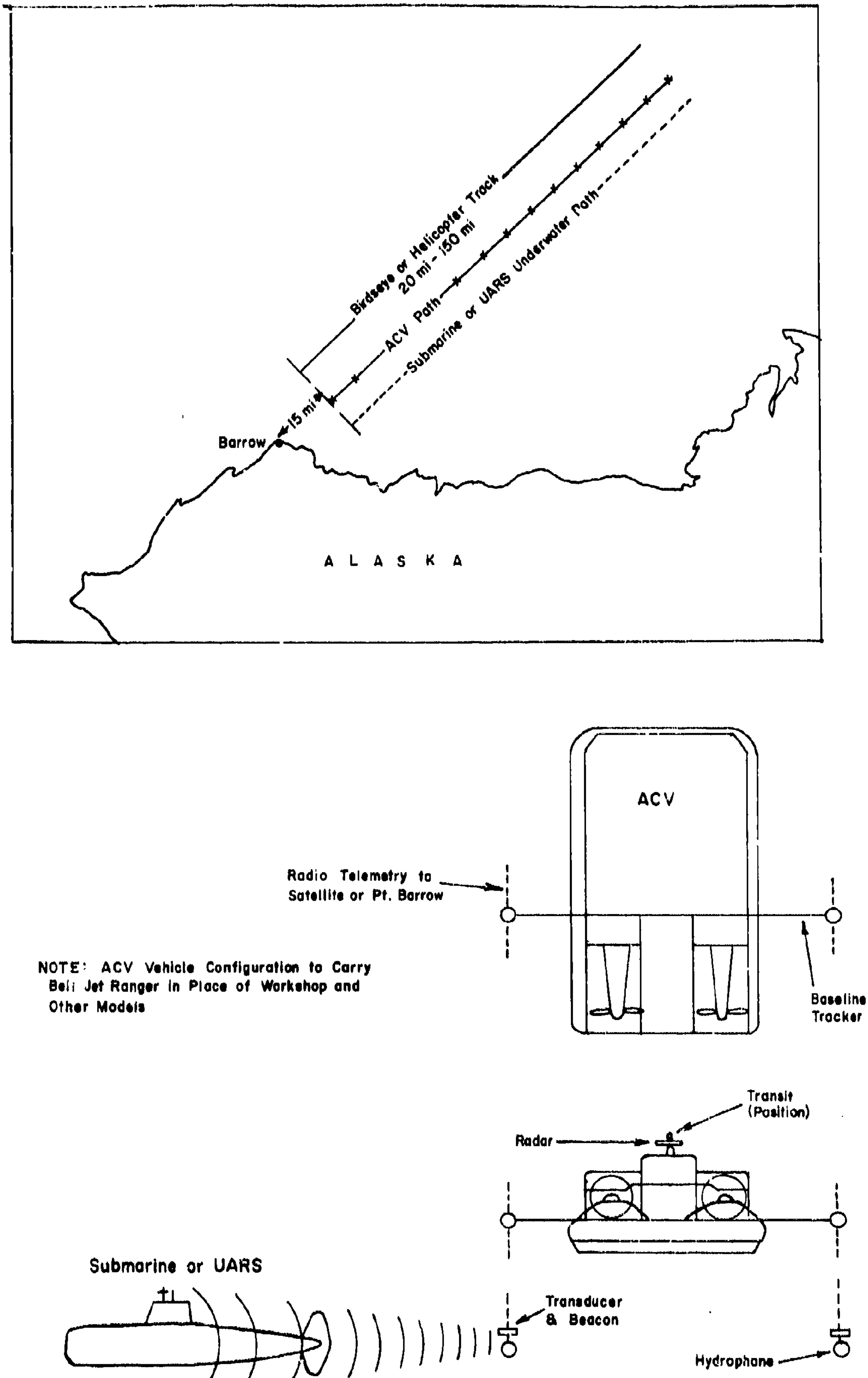


Figure 13. Sea Ice Profiling

TABLE XV

SEA ICE PROFILING MISSION DATA SHEET (ACV/HELICOPTER/UARS*)

Route distance (round trip) (100-mile profile track)		230 miles
Fuel consumption		
Running at 200 gal/hr		1,532 gal
Idle at 60 gal/hr		1,200 gal
Mission time		6 days
ACV running time		7.66 hours
Station stops		5
Refueling stops		None
	#001	#003
Available payload	37,784 lb**	36,112 lb**

*UARS assumed available at NARL at no cost.
Operation based on minimum 8-hour winter day.
Helicopter is Model 205 with laser profiler installed
Daily rental rate assumed to be $184/hr (minimum 3 hours).

** Fuel tanks full

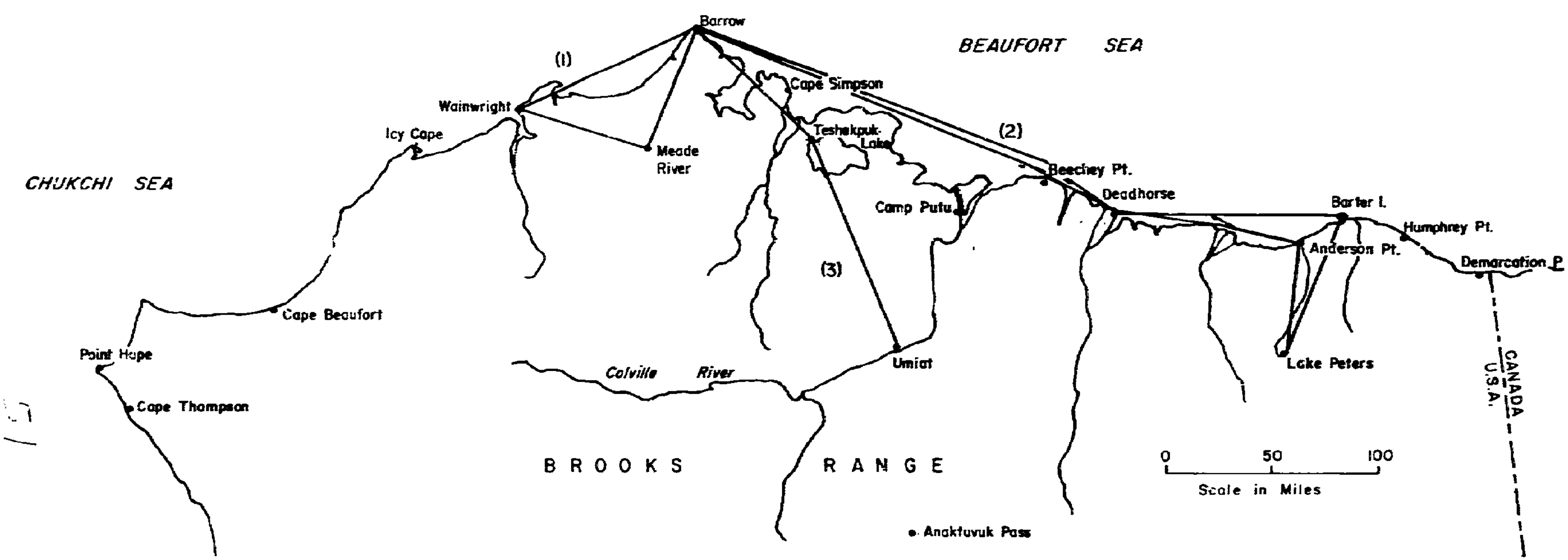


Figure 14. NARL Field Station Resupply

The configuration of the vehicle (ACV) is void of laboratory modules, although these modules could be added at the expense of available payload if scientific effort is required.

Trip 1 (4.5 hours). This is a direct run with an intermediate stop at Wainwright. Cruising at 30 miles per hour, the ACV can carry a payload of approximately 10 tons. No refueling stops are required.

Trip 2 (4 days). With the same vehicle configuration as in Trip 1, the intermediate routing plan of the ACV is as follows:

a. A direct run from NARL to Deadhorse (approximately 195 miles). At 30 miles per hour average, the running time is of the order of 6.5 hours. Cargo and passengers will be unloaded and the ACV refueled. The latter operation will consume 1 hour. The above activity concludes one day of operations.
b. On the second day, starting from Deadhorse, the ACV proceeds to Lake Peters via Anderson Point, a distance of 175 miles. Running at cruising speed, the travel time is approximately 5.75 hours. Discharging cargo and refueling will complete another day of activity.
c. Leaving Lake Peters, the vehicle journeys to Barter Island and Deadhorse, the initial legs of the return trip. From Lake Peters to Barter Island is 85 miles (2.75 hours ACV running time). It is approximately 105 miles to Deadhorse from Barter Island (roughly 3.5 hours of travel by ACV). At Deadhorse the ACV will lay overnight which concludes the third day of operations. The ACV will be refueled for the long journey to Point Barrow.
d. ACV travel time to NARL is 6.5 hours--a distance of 195 miles.

Trip 3 (2 days). The destination of this journey is Umiat. Routing of the ACV is through Teshekpuk Lake where a fuel cache of 100 drums will be established. The run to the lake is 80 miles (3 hours ACV time at 30 miles per hour). There the craft will refuel and proceed to Umiat, a distance of 95 miles (3.25 hours ACV operating time). Allowing for an overnight stay at Umiat, after unloading cargo and personnel, the ACV will again fill its fuel tanks for the return run to NARL which should consume 6.5 hours of running time.

This trip will be accomplished with the standard 3-man ACV crew. Housing and messing will be provided for all personnel aboard the craft on an as-required basis. (Table XVI is a data sheet for this mission.)

TABLE XVI

NARL FIELD STATION RESUPPLY MISSION DATA SHEET

Route distance (round trip)		
Trip 1--Barrow to Wainwright to Meade and return		130 miles
Trip 2--Barrow to Lake Peters via Barter Island and return		755 miles
Trip 3--Barrow to Umiat via Lake Teshekpuk and return		350 miles
Fuel consumption		
Running at 200 gal/hr	Trip 1	945 gallons
	Trip 2	5,250 gallons
	Trip 3	2,625 gallons
Mission Time	Trip 1	4.5 hours
	Trip 2	4 days
	Trip 3	2 days
ACV running time	Trip 1	4.5 hours
	Trip 2	26.5 hours
	Trip 3	12.5 hours
Station stops	Trip 1	2
	Trip 2	6
	Trip 3	5
Refueling stops	Trip 1	None
	Trip 2	2 Deadhorse
	Trip 3	1 Teshekpuk Lake

	#001	#003
Available payload	37,784 lb*	36,112 lb*
Committed cargo weight	2,000	2,000
Passenger load (3 men at 280 each)	840	840
Total committed weight	2,840	2,840
Spare payload	34,944	33,270

* Fuel tanks full

Other Missions

Additional missions suggested for ACV application which have not been described or analyzed in this report but may become assigned tasks of NARL include:

Fast ice coastal studies
T-3 and satellite drift station resupply
Geophysical investigations
Emergency rescue

SECTION V

TECHNICAL TRADE-OFFS

Since the Voyageur (#001) is currently undergoing acceptance testing, the quantity of performance data available is rather limited and the following evaluations are keyed to actual operating data supplied by the manufacturer. The trade-off considerations are as follows:

1. Weight versus endurance or range.
2. Fuel versus range.
3. Speed versus fuel consumption.
4. Slope capability versus load.
5. Maneuverability versus load.
6. Weight distribution versus mission.

1. Weight Versus Endurance or Range. Assuming the gross weight of the Voyageur to be 88,000 pounds and a fuel load of 3,000 pounds (equivalent to about 2 hours of running time), the craft will accommodate 24.5 tons of payload for a distance of 80 miles. (See Figure 15.) Increasing the fuel capacity to the maximum 8 tons will allow 12 hours of running time and a payload of 18 tons.

2. Fuel Versus Range. Figure 15 expresses a direct linear relationship between the fuel consumed and the range of the vehicle. With the tanks at 20 percent capacity (1.5 tons of JP5), Voyageur #001 has an operating range of 80 miles. As the fuel is increased to full capacity (8 tons), the range is extended to 480 miles.

3. Speed Versus Fuel Consumption. The manufacturer indicates that vehicle performance tests show very little change in fuel consumption within the range of 10 mph to 40 mph. In effect, one can expect negligible change in efficiency of operation by varying the speed of the craft.

4. Slope Capability Versus Load. Appendix A indicates that Voyageur #001, when unloaded, will maintain a continuous grade capability of approximately 15 percent. This capability decreases to about 5 or 6 percent when the ACV is fully loaded.

5. Maneuverability Versus Load. Here we are investigating the benefits derived from varying the payload in terms of ease of executing turns and overcoming ice ridges over 4 feet in height. Although the manufacturer is unable to furnish actual performance statistics demonstrative of any benefit, Bell's present indications are that variances, if any, are not measurable.

6. Weight Distribution Versus Mission. With the Voyageur #001 configured as a complete mobile laboratory, the available payload it can handle is approximately 5 tons in an area of 162 square feet (9 by 18 feet).

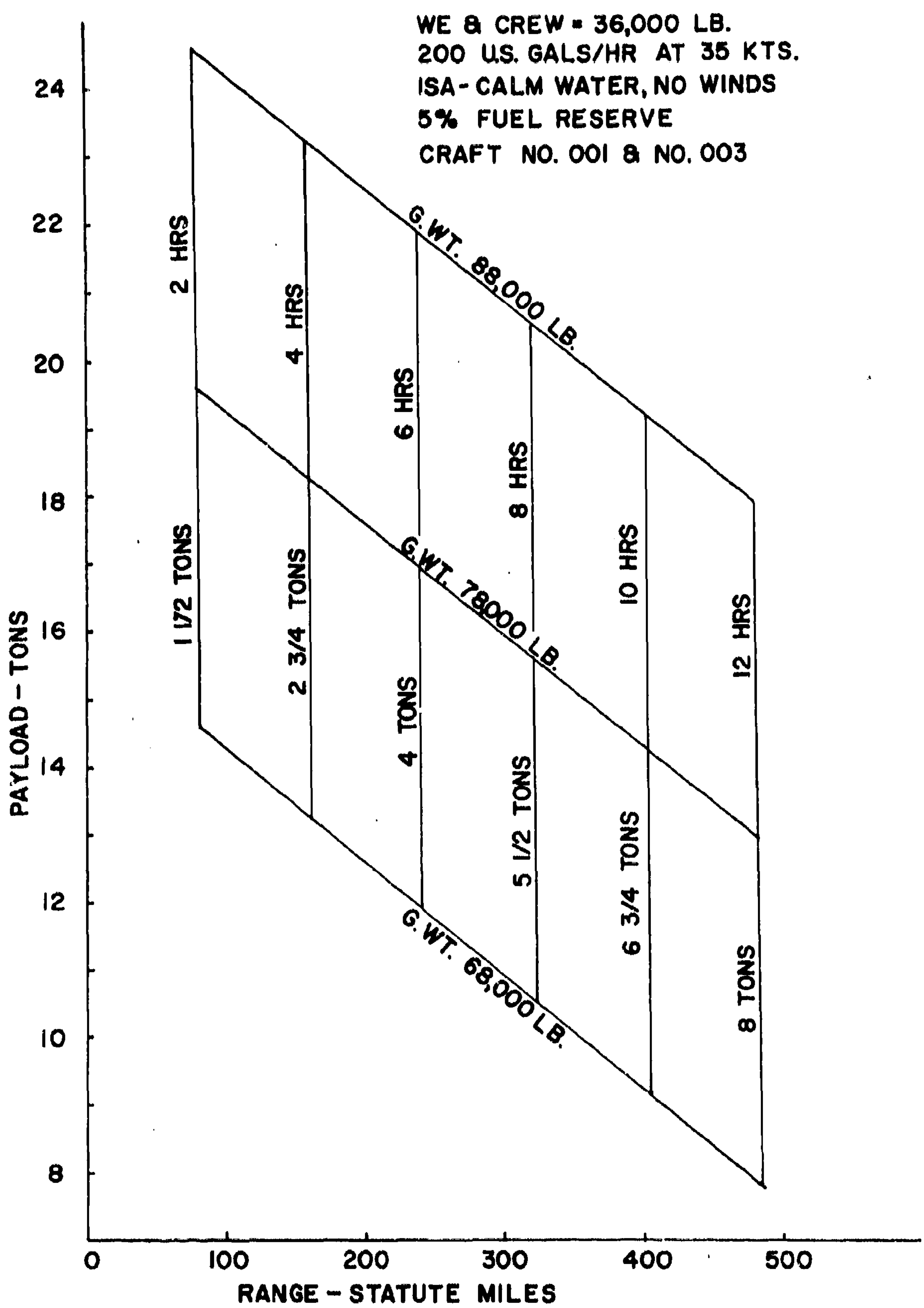


Figure 15. Payload/Range/Fuel Chart (Provisional)
Data Furnished By Bell Aerospace Co.

With all laboratory modules and the ancillary equipment for the mobile scientific station configuration removed, the actural cargo space available is 32 by 40 feet or 1,280 square feet which will support a payload of 17.4 tons. These tonnages are in excess of full fuel tanks and the weight of the operating crew and their equipment. The Voyageur, when operating in a major resupply mission of over 25 tons, could not compete with a C-130 for hauling cargoes over distances of several hundred miles.

SECTION VI

COST ANALYSES

LEASING COSTS

ARCTIC TRANSPORTATION

Vehicle	Rate*
C-130	$ 1,340/hr
R4D Cessna	$ 200/hr
Twin-Otter	$ 345/hr
Bell Helicopter	$ 184/hr
Helicopter (Jet Ranger)	$ 205/hr
Nuclear Submarine (Skate Class)	$40,000/day
Icebreaker (Wind Class)	$ 8,000/day

* All aircraft less fuel costs

Source: AIDJEX/NARL

ACV FIXED COST COMPUTATION

Vehicle Purchase

	Voyageur #001	Voyageur #003
Initial vehicle cost	$ 850,000	$1,300,000
Shipping (Ontario to Pt. Barrow)	46,000	46,000
Craft assembly/disassembly	10,000	10,000
Spares (8%)	68,000	104,000
Arctic conditioning	20,000	-
Modifications (modules/ancillary equipment	37,000	37,000
Procurement costs (6%)	51,000	78,000
Total expenditures	$1,082,000	$1,575,000
Operating costs:		
Annual fixed costs		
Depreciation to 10% of original value over 10-year life cycle.	$ 97,000	$ 141,750
Insurance (2.5%)	27,050	39,375
Interest on capital (6%)	64,920	94,500
Crew costs (salaries/fringe/ G&A/profit)	73,760	73,760
Misc. supplies & mech. tools	2,000	2,000
Factory tech. support	8,000	8,000
Vehicle maintenance	52,200	57,420
Total annual fixed costs	$325,310	$ 416,805
Fixed costs/hour	$212	$272
Annual utilization	1,528 hours	1,528 hours
Fixed costs/day (191 days)	$1,710	$2,180

BOTTOM SAMPLING MISSION
(Sea Ice)

COST COMPARISIONS

	ACV P	ACV L	Helicopter	Icebreaker[1]
Vehicle charge (daily rate[2])	$1,710	$3,160	$ 1,472	$ 8,000[3]
Mission cost[5]	$5,466	$9,816	$10,416	$32,000
Total route miles	250		750[4]	250
Mission time	3 days		7 days	4 days
Refueling stops	-		7	-
Fuel consumption				
Gallons	1,685		560	-
Cost	$336		$112	-
Route obstacles	Ice ridges		Bad flying weather	Thick pack ice and low visibility

P= Purchase plan
L= Lease plan
[1] With helicopter aboard
[2] Based on 8-hour operating day
[3] Includes fuel costs
[4] Average flying distance/day = 100+miles
[5] Housing and messing incidental cost not included

NARL FIELD STATION RESUPPLY
(Trip 2)

COST COMPARISONS

	ACV		
	P	L	C-130
Vehicle charge (daily rate)	$1,710	$ 3,160	$10,720
Mission cost (incl. fuel)	$7,900	$13,700	$11,200
Total route miles	755		755
Mission time	4 days		1 day
Refueling	2		–
Fuel consumption			
Gallons	5,300		2,400*
Cost	$1,060		$480

*C-130 version with fuel tanks that carry this requirement

NARL FIELD STATION RESUPPLY
(Trip 3)

COST COMPARISONS

	ACV P	ACV L	R4D
Vehicle charge (daily rate)	$1,710	$3,160	$1,600*
Mission cost (incl. fuel)	$3,945	$6,845	$1,672
Total route miles	350		300
Mission time	2 days		1 day
Refueling stops	1		–
Fuel Consumption			
Gallons	2,625		360
Cost	$525		$72

*Based on 8-hour day

AIDJEX SATELLITE CAMP OPERATIONS MISSION
(Ferrying Cargo and Personnel)

COST COMPARISONS

	ACV P	ACV L	Helicopter	Twin-Otter
Vehicle charge (daily rate)	$1,710	$3,160	$1,472	$2,760
Mission cost (incl. fuel)	$1,970	$3,420	$ 603*	$1,077*
Total route miles	200		180	
Mission time	8 hours		3 hours	
Refueling stops	-		-	
Fuel consumption				
Gallons	1,300		240	210
Cost	$260		$48	$42
Route obstacles			Bad flying weather	

P= Purchase plan
L= Lease plan

* Minimum daily lease = 3 hours

NARL ANNUAL RESUPPLY LIGHTERAGE MISSION
(Sea Ice)

COST COMPARISONS

	ACV		NARL
	P	L	Cool Barge Backhaul
Vehicle charge (daily rate)	$1,710	$3,160	
Mission cost (incl. fuel)	$14,475*	$23,900*	
	$25,590**	$44,440**	
Total route miles	1,050		
Mission time (days)	6.5*		
	13.0**		
Refueling stops	24*		
	13**		
Fuel consumption			
Gallons	16,800		
Cost	$3,360		
Route obstacles	-		Drifting pack ice blockage

*24-hour day

** 10-hour day

DATA BUOY DEPLOYMENT AND MIZ INVESTIGATION MISSION

COST COMPARISONS

	ACV		
	P	L	Icebreaker
Vehicle charge (daily rate*)	$1,710	$3,160	$8,000**
Mission cost (incl. fuel)	$14,881	$23,700	$140,000
Total route miles	1,000		900
Mission time (days)	7.5		17.5+
Refueling stops	4		-
Fuel consumption			
Gallons	10,280		-
Cost	$2,056		-
Route obstacles	Ice ridges		Thick pack ice, low visibility

*Based on 8-hour operating day

** Includes fuel costs

+ Icebreaker average speed is 2-5 knots

SEA ICE PROFILING MISSION
(Winter Operation)

COST COMPARISONS

ACV/Helicopter/UARS

	ACV P	ACV L	Helicopter	Drift Station*	Birdseye A/C	Nuclear Submarine
Vehicle charge (daily rate)	$1,710	$3,160	$550	$12,000	$12,000	$40,000
Mission cost	$10,806	$19,506	$3,000		$220,000	
Total route miles		230			230	
Mission time		6 days			4 days	
Refueling Stops		--			--	
Fuel consumption						
Gallons	2,732**		1,200			
Cost	$546		$240			
Route obstacles			Bad flying weather		Bad weather	

BERING SEA OCEANOGRAPHICS MISSION

COST COMPARISONS

	ACV P	ACV L	Icebreaker
Vehicle charge (daily rate)	$1,710	$3,160	$8,000*
Mission cost (incl. fuel)	$30,169	$52,644	$120,000
Total route miles	2,500		2,500
Mission time	15.5 days		15 days
Refueling stops	8		--
Fuel consumption**			
Gallons	18,320		--
Costs	$3,664		--

*Includes fuel costs

**Assumes ACV refueling on station

SECTION VII

IMPLEMENTATION PLAN

The number and variety of missions recommended for ACV application indicate that the vehicle should be required for a minimum operational period of 1 year. During this interval the all-season capability of the vehicle can be fully determined as well as any long-term craft operating problems associated with exposure to extreme environmental conditions.

Assignment of the ACV for a minimum period of 1 year will permit NARL planners to schedule and assign missions for the ACV to suit the preprogrammed timetable of committed NARL projects.

It is estimated that approximately 2 months are required from the date of vehicle acquisition to effect vehicle modifications, install the full laboratory configuration, disassemble, ship, and reassemble the craft at NARL.

Once the vehicle is assembled, 15 to 30 days should be allowed for arctic conditioning (assuming Voyageur #001 is acquired) and to permit vehicle trial runs in the local area to familiarize the crew and NARL base personnel with the terrain and logistic support facilities needed. During this trial period, ACV mission plans should be formulated and schedules developed to commit the craft to the maximum number of available operating hours. In this regard, mission schedules will be tailored to scientific project requests received through the Director of NARL or his designated transportation officer.

Routine maintenance schedules and 1,000-hour engine inspection assignments will be developed and published to facilitate the availability of maintenance shop support and to apprise operations planners of when the ACV will be out of service.

If the opportunity is right, the ACV should be assigned to a T-3 resupply mission to determine the practical application of an ACV to short-distance cargo handling roles.

A sample implementation schedule is furnished in Figure 16.

It has been assumed that since Voyageur #001 is presently available, the various milestones of Figure 16 can be achieved during calendar year 1972 and the early part of 1973. In the event that the craft is no longer available, Bell Aerospace indicates a minimum waiting period of 12 months before #003 will leave the production line which extends the suggested schedule by 1 year.

ARO

MONTHS

July	August	September	October*	November*	December*	January**	February*	March*	April*	May*	June*
ACV Factory Mods, Ship to Pt. Barrow Prepare hangar area	Craft Assembly and Arctic Conditioning	ACV Test Runs	NARL Field Supply	Field Station Support	Bottom Sampling	MIZ Ops	MIZ and Buoy Deploy Ops	AIDJEX Sat Camp Support	AIDJEX Sat Camp Support (cont.)	Sea Ice Profiling	Bering Sea Oceanographics

AVAILABLE MISSION TIME (October – June)

* = 100-hour maintenance check (1 week)
** = 1,000-hour engine check (1 week)
Assumption: ARO Date of 1 July 1972

FIGURE 16. ACV Implementation Milestones

APPENDIX A

Voyageur Air Cushion Vehicle Model 7380 (Serial No. 001 and 003)

General Description

Voyageur (Figure A-1) is a rugged, all-metal craft constructed of corrosion resistant 6000 Series aluminum. The design of the modular structure incorporates hollow-core, thin-walled aluminum extrusions similar to those used in military and commercial ships. Use of this material, together with extruded corners for constructing the joints, produces a structural box of great stiffness. Flat surfaces are used wherever possible, eliminating the need for formed parts and thus simplifying repairs. The structural modules are welded with the gas-shielded metal arc and the gas-shielded tungsten arc process.

The craft is powered by two General Electric LM-100 power plants (#001) or by two Twin Pac ST6T-75 marine gas turbine engines (#003). Each engine drives a propulsion air propeller and a centrifugal lift fan. The twin engine/propeller layout gives reliability in combination with greatly improved control. Pitch of both propellers is reversible, and fins mounted aft of the propellers give increased directional stability and control. The lift fans are mounted forward of and below the propellers, air being drawn by the fan through the large annular intake and directed through plenum chambers into the peripheral trunks. From the trunks, the air is directed inboard beneath the craft to provide the air cushion.

The control cabin is supported on a simple truss structure and located toward the rear of the craft. The cabin will provide comfortable seating for the vehicle operator, the assistant operator/navigator, and for the mechanic/handler. Instruments, communications, controls, and radar systems are carefully sited for accessibility and reduction of operator fatigue. Large windows assure a 360-degree field of view.

The main deck is designed to accept loading of up to 1,000 pounds per square foot. Cargo tiedown rings (Figure A-2) and craft handling and mooring gear are provided. When the vehicle is off-cushion, the cargo deck is low enough to permit rapid loading and unloading from trucks or forklifts. Access to the control cabin is provided by ladders and walkways.

The craft is completely amphibious and the hull is divided into separate watertight compartments with a reserve buoyancy in excess of 100 percent. The trunks and skirts are designed to reduce air leakage to a minimum. Skirt materials have been selected to give extremely long life when traveling over land or water.

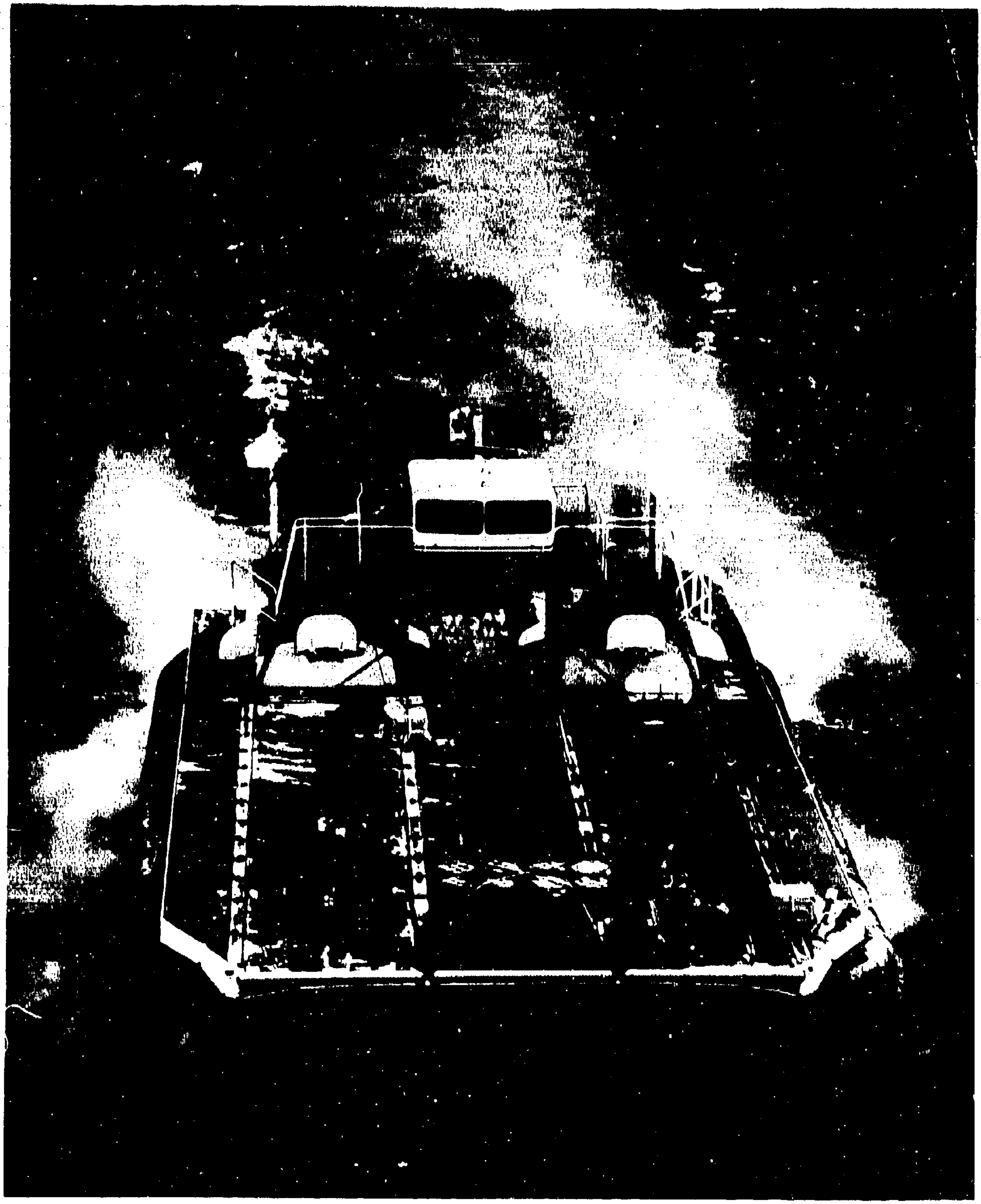


Figure A-1. Bell Voyageur Model 7380 (Photo Supplied by Bell Aerospace Co.)

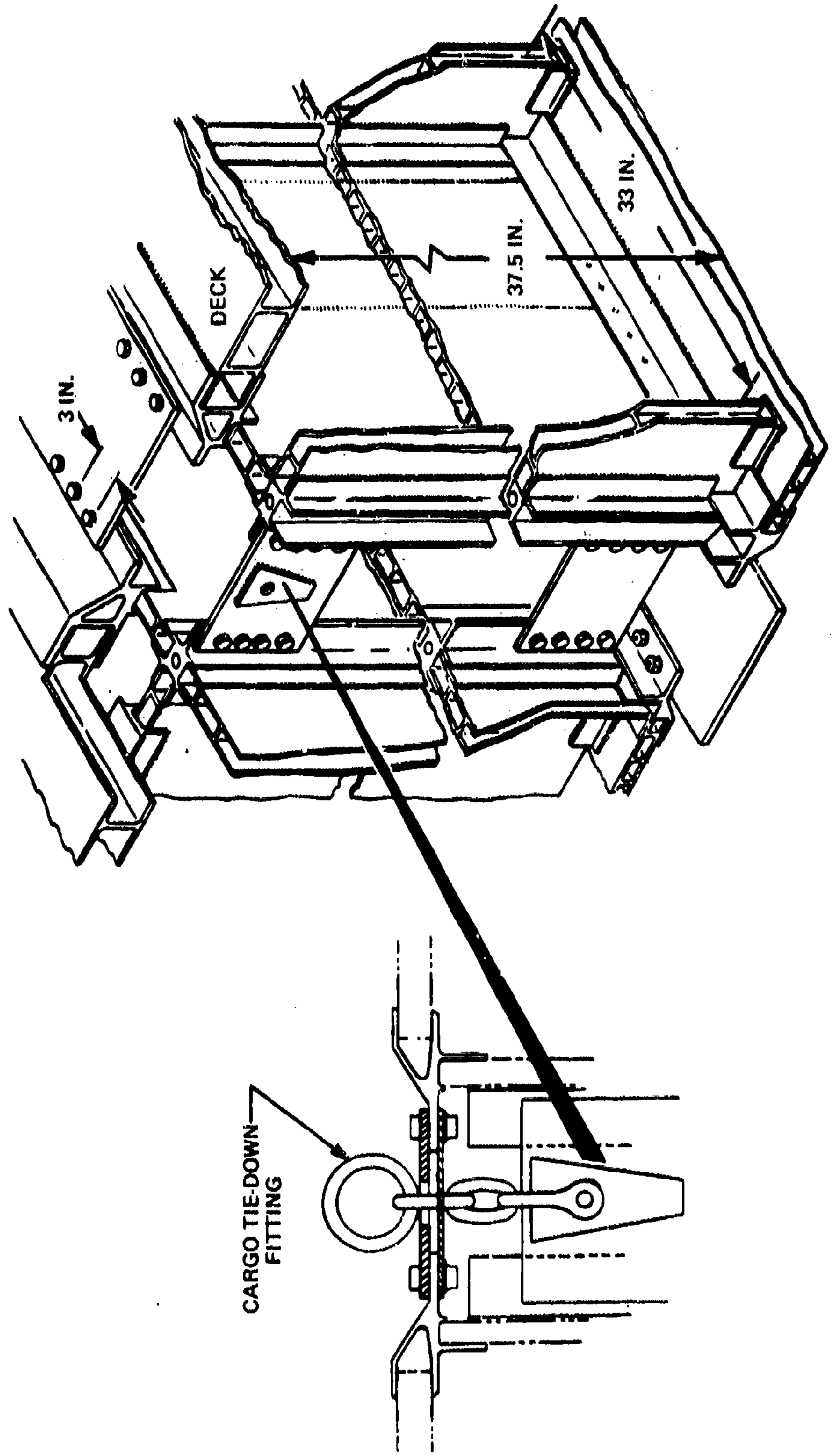


Figure A-2. Cargo Tiedown Fitting Detail

The inclusion of operationally proven power components (with actual operating history in many parts of the world) significantly minimizes craft maintenance requirements. Voyageur incorporates the best features available today and thus provides a reliable, safe, comfortable, and economic means of performing the mission.

Design and Engineering Features

1. Voyageur Leading Particulars

The general arrangement of the basic Voyageur vehicle is shown in Figure A-3. The weight summary and specifications are listed in Tables A-I and A-II The design meets or exceeds Air Cushion Vehicle Regulations and Certification Requirements of the Canadian Ministry of Transport and the U.S. Coast Guard.

2. Design and Engineering

The primary features in the design of Voyageur are the low-cost, long-life structure, the use of proven propulsion and lift systems, and the large deck area for operational flexibility. To ensure high utilization in-service rates, the design has been tailored to a maintenance system using component replacement techniques. The following descriptions of the craft's design and engineering features apply to the basic flatbed configuration.

a. Structure

Bell studies have shown that hollow-core, extruded panel sections offer many advantages for primary structures. Panels of this type are currently used in military and commercial ship superstructures. This material with its extruded corners for joining of paneling and bulkheads makes a structural box of great stiffness under high shear, torsion, and compression loadings. The requirements for a low-cost, rugged structure to withstand expected operational usage and the capabilities of hollow-core panels complement each other. The hull structure design eliminates formed parts and greatly reduces tooling costs. Additionally, wherever possible, welding is used to join the extrusions for further cost savings.

The craft structure is designed to be broken down and transported in twelve sections (Figure A-4). These consist of three forward flotation boxes, two forward and two aft side decks, two power modules, an aft center flotation box, a cabin support pedestal, and the control cabin.

The three forward flotation boxes are similar and nominally measure 40 feet long, 8 feet wide, and 37-1/2 inches deep. The major difference in these boxes is that the port and starboard boxes each contain a fuel tank comprising three interconnected cells and a landing pad support structure.*

*BAC Proprietary Information

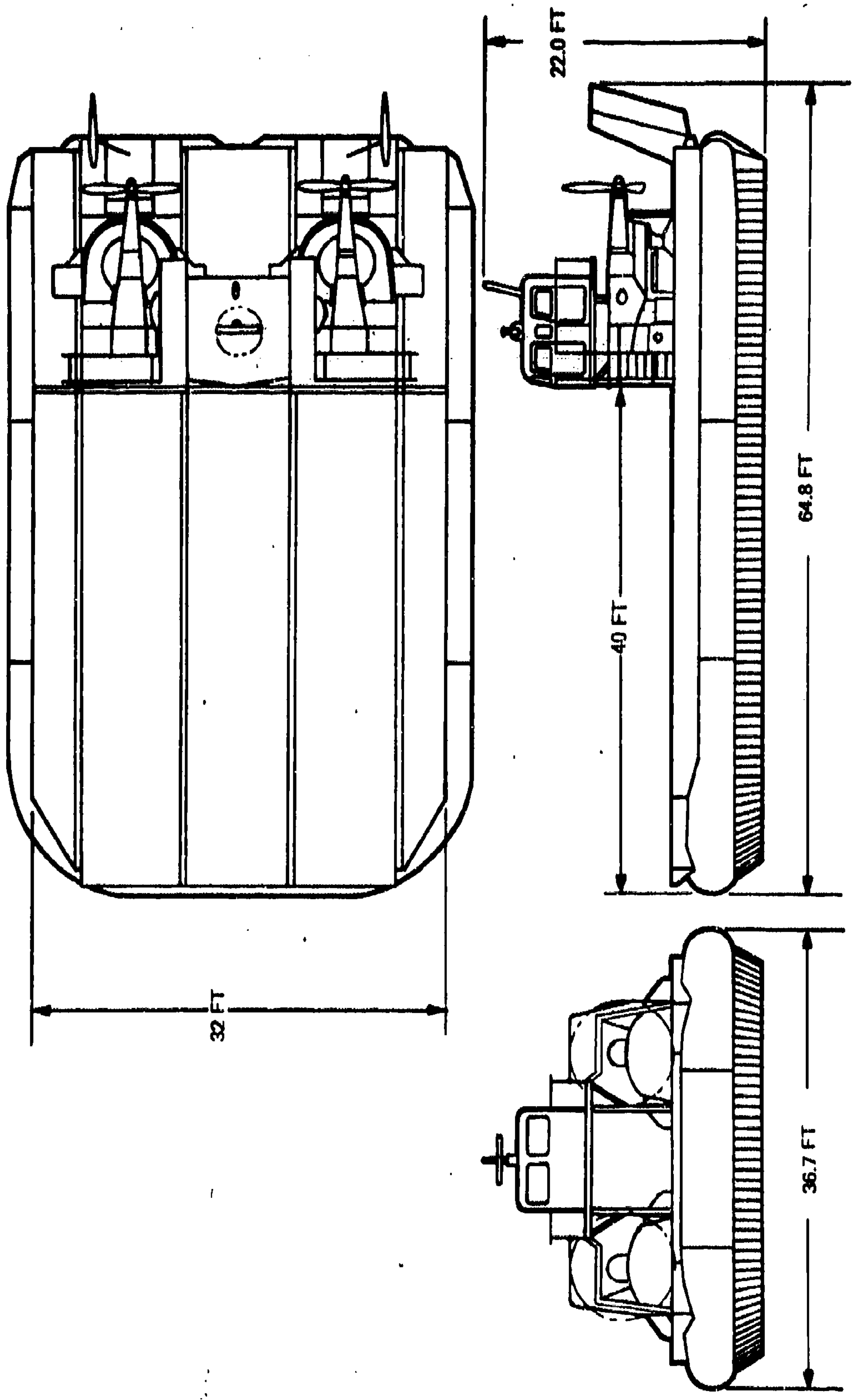


Figure A-3. General Arrangement - Voyageur

TABLE A-I

WEIGHT SUMMARY (LM-100 ENGINES)

Item	Pounds
Basic Structure	21,039
Crew Station	2,459
Propulsion System	5,016
Electrical System	431
Controls	94
Skirts, Landing Pads	3,596
Fins and Rudder	147
Exterior Finish	349
Furnishings	647
Miscellaneous	118
Basic Weight Empty	33,896
Crew (Operator and Navigator)	380
Operating Weight Empty	34,276
Fuel, nominal, 600 U.S. gallons	4,080
Payload	39,644
Design Gross Weight	78,000
Fuel (or Payload)	10,000
Maximum Permissible Gross Weight	88,000

TABLE A-II
SPECIFICATIONS

Bell Aerospace Designation	Model 7380, Voyageur
Application	Heavy Haul Transport
Operating Crew	Commander, Navigator/Radio Operator
Capacity	Up to 25 tons
DIMENSIONS	
Length, overall	64.8 ft
Beam, overall	36.7 ft
Height, overall (on cushion)	22.0 ft
Height, overall (off cushion)	18 ft 10 inches
Height of cargo deck (off cushion)	46 inches
Skirt height, nominal	4.0 ft
Cushion area	1789 sq ft
Cushion loading at 88,000 lb	49.2 lb/sq ft
Buoyancy reserve at 88,000 lb	125%
Cargo deck	40 x 32 ft (1280 sq. ft)
POWER MODULES	
Engines	Two General Electric LM-100 PD-101 Marine Gas Turbines Maximum continuous power 1000 shp
Transmission (2)	Integrated drive for lift fan and propeller
Propellers (2)	Hamilton Standard, Model 43D50, three bladed, 9 ft dia, controlled pitch
Lift Fan (2)	7 ft dia, twelve bladed, fixed pitch, centrifugal
FLEXIBLE TRUNKS	4 ft combination type with 50% fingers
FUEL SYSTEM	
Type	Standard aviation kerosene (AVTUR) JP4, or JP5
Tanks	Six in groups of three
Capacity	2400 U.S. gallons
Boost Pumps	Vane Type, 120 U.S. gallons per hour
ELECTRICAL SYSTEM	
Generators (4)	Gearbox driven brushless, supply 28 volts, D.C.
Batteries (2)	Nickel-Cadmium, 28 volt
External power	28 volts D.C.

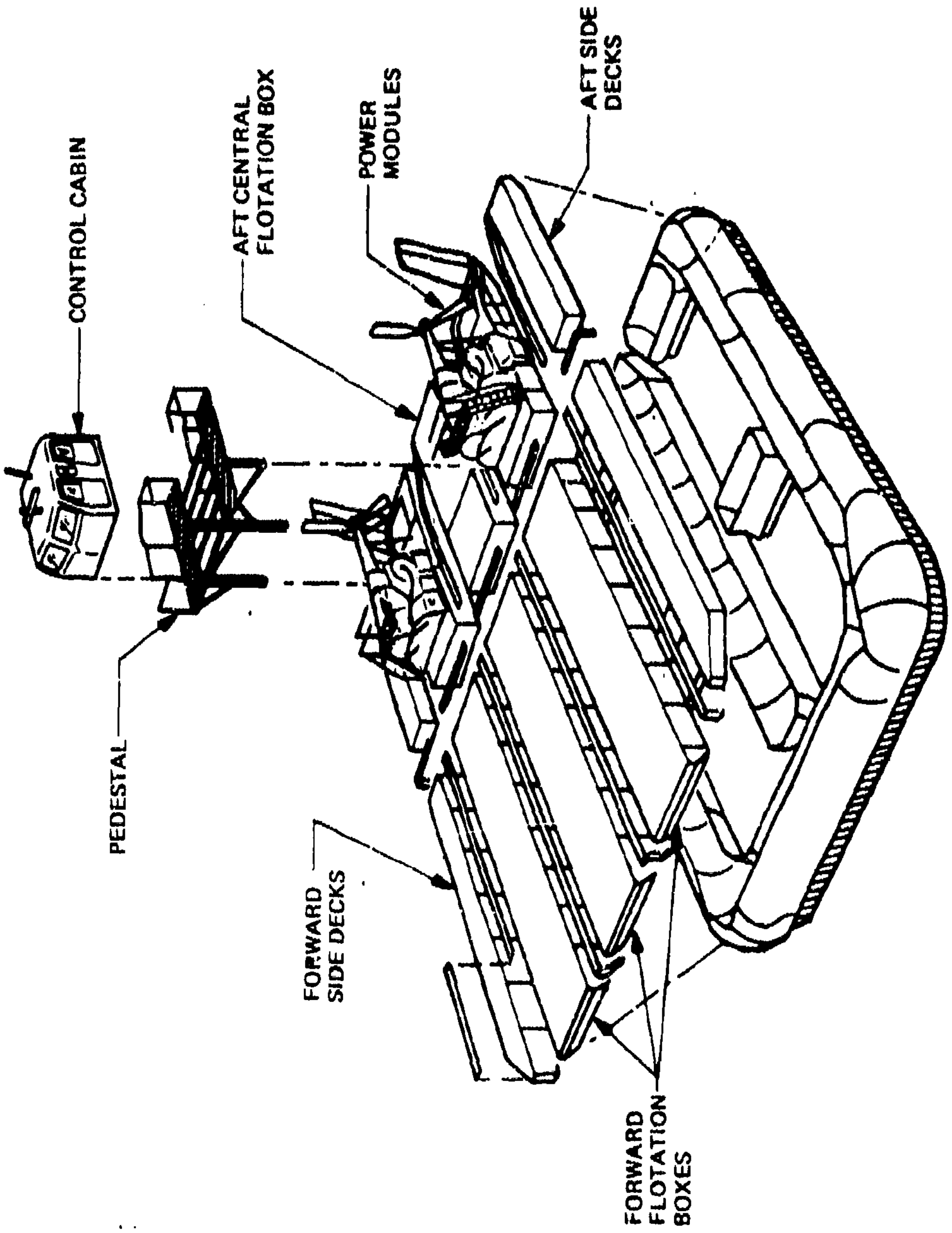


Figure A-4. Exploded View of Voyageur Modules

The aft center flotation box is of similar construction to the forward boxes, but shorter in length with scallops formed in each side to prevent airflow blockage around the perimeter of the lift fans. The lift fans are contained in the power modules situated on either side of the center box. Loads from the side decks and the power modules are transmitted into this primary structure.*

With the exception of those portions of the SK-5 used in the power modules, all other structural sections are fabricated from 6000 Series aluminum extrusions and plates. Extrusions are in the form of hollow-core planking, joint sections, and square section tubing. Welding is used to join the extruded sections, but when riveting is necessary, a sealant is used between the surfaces, and blind rivets wetted with sealant are installed.*

Three different sections of hollow-core planking are used in the craft structure. The heaviest is used for the upper decking on the forward flotation boxes where the maximum logitudinal bending moment occurs, in addition to allowing 1,000 pounds per square foot cargo limit loading. The next heaviest section is used for the bottom planking on all forward and the aft center flotation boxes. This planking is also used on the deck of the forward side hulls and the aft center box, where the deck limit load is also 1,000 pounds per square foot. The lightest plank is used for the vertical bulkheads within the flotation boxes and for the decking on the aft side hulls of the craft where the deck limit load is 250 pounds per square foot.*

Transverse bulkhead spacing is basically 33 inches for the forward flotation boxes. The transverse structure in the aft section is on 29-inch centers, to be compatible with the SK-5/SR.N5 structure used in the power modules. Within the flotation boxes, selected bulkheads are made watertight to provide reserve buoyancy in the event of damage. Additionally, a buoyancy compartment has been provided at the aft end of the outboard side hulls. The end result of this compartmentalization is 24 individual buoyancy sections with a portable bilge pump. The total buoyancy of the craft is more than two times the normal design gross weight.

Four landing pads are provided to support the vehicle on hard surfaces. These are located on each outboard forward flotation box and on each power module. The pads are positioned sufficiently inboard to preclude damage to the side skirts when landing with sideslip. The pads are 10 inches in height and each has a ground surface area of approximately 530 square inches, giving an average footprint pressure of 37 pounds per square inch at a gross weight of 78,000 pounds. The pads are designed as replaceable foam-filled containers. The foam material will crush at 85 pounds per square inch to prevent damage to the primary hull structure. The ground contact surface is 1-inch thick oak. The metal container is 6061 aluminum with Nopcofoam H104 (density of 3.2 to 3.5 pounds per cubic foot) as the filling material.*

* BAC Proprietary Information

The individual hull modules are joined with horizontal and vertical splice plates and bolts. Cargo tie-down fittings are attached in a pattern of four rows and spaced 104 inches apart with the fittings located at 33-inch intervals along the row. Each of these steel tie-down fittings consists of a ring, chain links, and a shackle assembly, and has an ultimate load capacity of 15, 000 pounds. These fittings can be used in combination for hoisting the craft with appropriate slings. *

All splice plates are made of aluminum, except for a small section around each tie-down ring and at the bow towing eyes where steel is used. The four bow towing eyes are designed for an ultimate load of 10, 000 pounds each and are located at the forward end of each row of upper longitudinal splice plates. Two stern towing eyes provided at the corners of the aft center flotation box are designed for an ultimate load of 6, 000 pounds each. *

b. Skirt System

The skirt system has been developed with the British Hovercraft Corporation. The configuration is a modification of the proven SR. N6 design using 50-percent peripheral fingers (Figure A-5). The longitudinal keel, rear trunks, transverse stability trunks, and peripheral skirts are all extensions of the SR. N6 design. However, the skirts around the bow section transition to a higher outer attachment hinge line across the bow to maximize the overwater plough-in resistance of the craft. The skirt system is fabricated of neoprene-coated, single-ply nylon material. Material weights varying from 40 to 85 ounces per square yard are utilized in different portions of the skirt system. *

The airflow to the side and bow skirts is supplied through the ducts formed by the side hulls. The transverse stability trunks are also supplied from this side hull airflow through ducts built into the outboard forward flotation boxes immediately forward of the fuel tanks. The port and starboard rear trunks are supplied by rearwind airflow from their respective fans. The longitudinal keel is fed by ducts leading from each fan toward the center of the aft center flotation box and then downward into the keel bag. *

c. Fuel System

The fuel system of the craft has a total capacity of 2,400 U.S. gallons. A tank is provided in each of the forward outboard flotation boxes utilizing the space between transverse bulkheads to form individual fuel cells (Figure A-6). Three adjacent bays are used with appropriate interconnections. The fuel cells consist of a three-ply nylon material impregnated with Buna-N rubber to a thickness of 0. 024 inch. The bottom of each fuel bay is built up with foam and covered with fiberglass to reduce residual fuel weight and form a sump in the center cell. Each fuel cell contains two laced-in rubber baffles

*BAC Proprietary Information

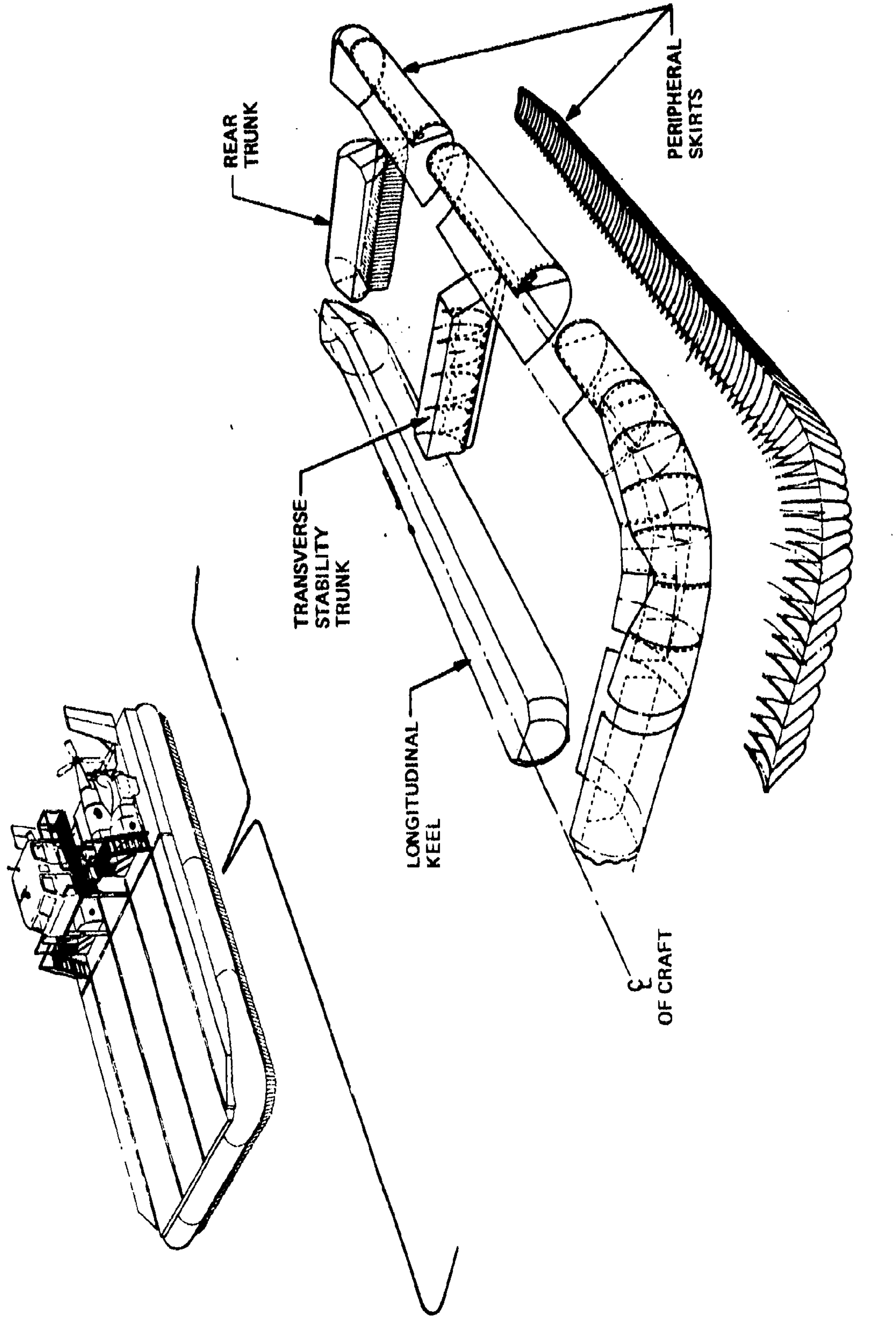


Figure A-5. Voyageur Skirt Configuration

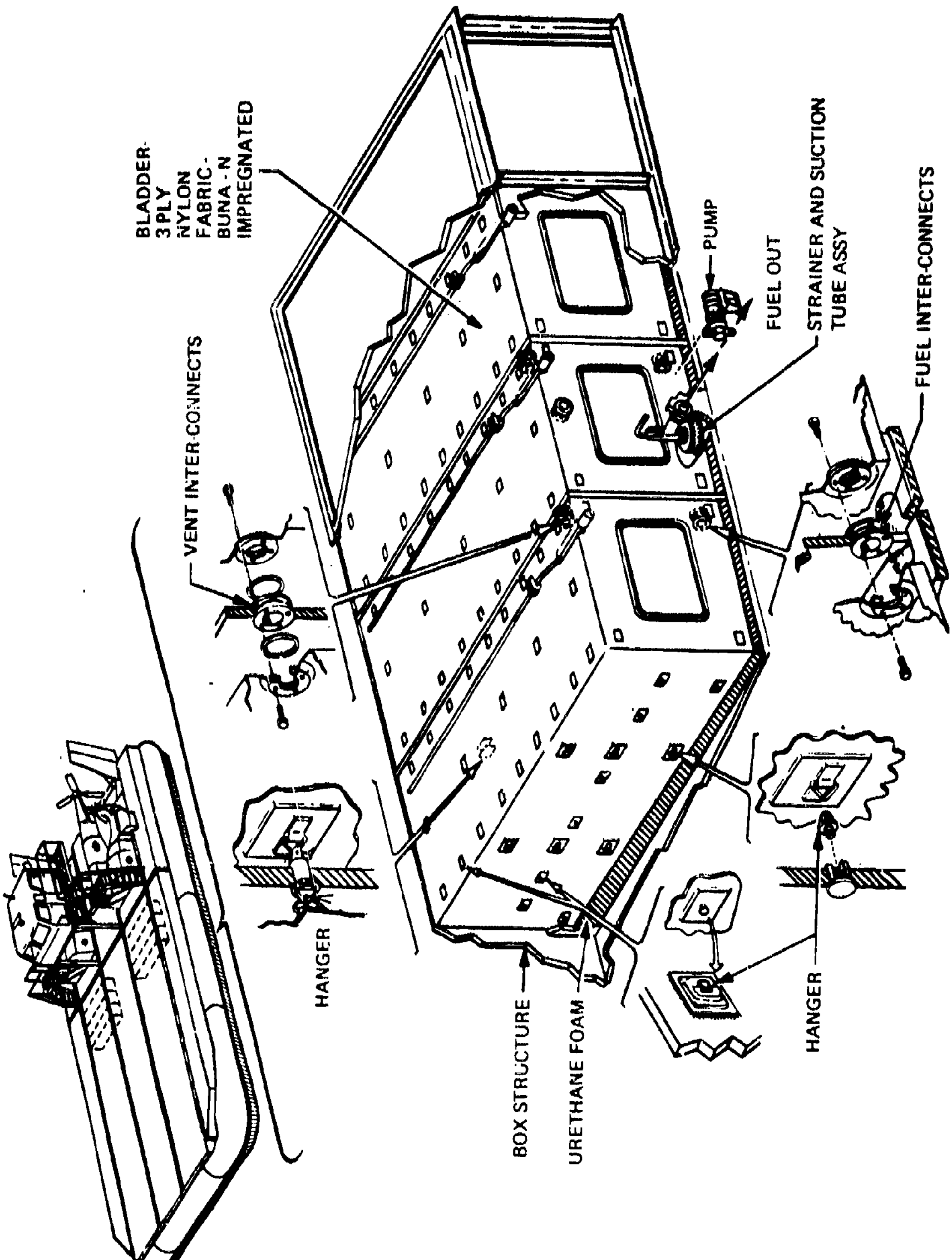


Figure A-6. Fuel Tank Installation

to minimize sloshing. Access doors permit installation and interconnection of the individual cells and are sealed with O-ring gaskets. Normally, the port and starboard tanks are not interconnected and each supplies its respective engine. However, fuel lines and an electrically operated valve are incorporated to permit operation on either tank. The fuel booster pumps are 28-volt, vane type units and can supply both engines at normal power. Fuel can be drawn from either tank by opening the crossover valve and turning off one booster pump. Should one booster pump fail, a low cracking pressure check valve in parallel with the pump enables normal engine operation to continue for a limited period on the engine-driven fuel pump only.*

The full fuel capacity designed into the vehicle is sufficient to allow a 40- to 45-mph cruise endurance of approximately 10 hours with a 20-ton payload. Maximum endurance of approximately 12 hours can be achieved by reducing the cargo to 15 tons. For operation over shorter stage lengths, internal fuel quantity can be reduced, thereby permitting the craft to carry additional cargo up to 25 tons.

d. Power Units and Transmission

Since the gear ratios between the engine, lift fan, and propeller are fixed, the power distribution can be altered by varying the propeller pitch. This action changes the speed of the system and alters the power absorbed by the lift fan. The power absorbed by the fan can be altered from almost zero (vehicle floating off-cushion with minimum power) to the maximum permitted by engine and propeller speed limitations. This arrangement is termed integrated lift/propulsion.

The main gearbox divides the drive between the fan and the propeller. The input gears mesh with pinions that drive the propeller pitch change hydraulic pumps. The front section of the propeller drive shaft is supported by roller bearings and a ball thrust bearing, and carries a bevel gear which drives the fan. A pair of tapered roller races transmit positive and negative propeller thrust force to the gearbox casing. Five jets supply lubricating oil directly to the meshing gears and bearings.

The lift fan rotates on tapered roller bearings fitted to a pintle in the base of the craft. The bearings are packed on assembly and no lubrication is required between overhauls.

Both engine installations are supplied with air from the cushion plenum. The air supplied to the compressor inlet is obtained through two intake ducts on each engine located on the inboard and outboard side of each lift fan. The velocity vector of the airflow separates dirt particles from the air entering the duct. The air is subsequently passed through a knit-mesh filter before entering the engine. This type of inlet filtering system was evaluated in sand conditions in the Libyan desert.

*BAC Proprietary Information

The 9-foot diameter, 3-bladed aluminum propellers are Hamilton Standard Model 43D50. Propeller pitch is controlled hydraulically, using hydraulic pressure developed by pumps mounted on the gearboxes. Leading particulars of the propeller are:

Weight	340 lb
Rotation	Clockwise (viewed from rear)
High pitch angle	+36 degrees
Reverse pitch angle	-25 degrees
Normal operating speed	1,300 to 2,000 rpm
Maximum rotational speed	2,200 rpm (engine overspeed)

e. Control System

The Voyageur control system is based on experience gained with extensive operation of previous craft including the Bell SK-5 and BHC SR.N5 and SR.N6 series. Control is obtained by varying the pitch angles of the propellers, either collectively or differentially, and through use of the two aerodynamic rudders. Provisions for the addition of puff ports are built into the craft. These puff ports operate on the same principle as bow thrusters on a ship and use air from the plenum to provide the necessary thrust.

The propeller pitch controls are located on the starboard side of the operator seat such that they can be positioned with the right hand while engine power is controlled with the left hand. Movement of the pitch control levers is transmitted to the gearbox through sealed Controllex cables. Spring dampers are incorporated in the system to limit the load that the operator can apply.

The twin-linked rudders are operated by an adjustable parallel motion rudder bar and provide directional control of the vehicle at speed. The position of the rudder bar is adjustable to suit the operator. Provision is made to lock the rudder control when not in use.

The vehicle control cabin is located in an elevated position between the power modules. From this location, the vehicle operator has a clear view of the forward half of the deck area while seated in the normal driving position. A full two-thirds of the deck is visible with the operator leaning slightly forward toward the windshield. Space is available under the cabin and between the support posts to accommodate cargo or small house-trailer type quarters. The accommodation module can extend both forward and aft of the undercabin area, readily permitting a 16-foot unit to be utilized. A typical commercially available 16-foot trailer can accommodate six men with full food storage and preparation facilities, closet space, sleeping bunks, toilet, air conditioning, and lighting. Headroom under the cabin is 6 feet 4 inches and unobstructed width between support posts is 7 feet 8 inches.

The control cab.n is a modified 4-door truck cab and has a width of 94 inches and a length of 104 inches. The operator's position is on the forward starboard side and the relief driver or radar operator is at the forward port position. Both forward seats are Bostrom Viking "T" Bar designs with arm rests and seat belts. The control console is located between the two seats and contains the controls for the engines and propellers.*

A full width bench seat is located across the back of the cab, with access provided by the two rear doors. Seat belts are installed for four passengers. Beneath the bench seat, equipment for the air-operated windshield wipers and washing system is installed. The windows are of tinted, tempered glass and provide visibility through 360 degrees. Windshield wipers are installed on the two forward windows and on the center aft window. *

Incombustible insulation is installed on the walls and roof of the cab and under the floor. An air-conditioning unit can also be provided together with the necessary ducting for windshield demisting and defrosting.

f. Electrical System

The electrical system is a 24-volt, negative ground return system comprising Lear Siegler starter generators and associated Bendix solid-state voltage regulators operating in conjunction with nickel-cadmium batteries. The four starter generators are driven from the connecting gearbox and are rated at 200 amperes at 28 vdc. Two generators are sufficient to supply normal craft electrical requirements. Power required to operate special equipment items such as boom cranes or winches must be supplied from an independent electrical or hydraulic power source. *

The two nickel-cadmium batteries are rated at 34 ampere-hours. The generators and batteries are interconnected to permit charging from any generator. Similarly, engines can be started from any battery. When the engines are running, the batteries are paralleled. Each battery is capable of three engine start cycles at -40°C. Provision is made for connecting to a 28-vdc external power source. *

The remote indicating magnetic compass is supplied with AC power from a static inverter at 26 volts, 400 Hertz. AC power for the Decca radar is supplied by the radar power supply unit. *

The circuit breaker panel, electrical control panel, and switch panel are located in the control cabin. The operator's panels (Voyageur #001 only) contain the following displays:

Interturbine temperature gauge (2)
Gas generator rpm (2)
Power turbine rpm (2)
Fuel content lights (2)
Fuel pressure lights (2)

*BAC Proprietary Information

Magnetic compass
Oil pressure lights (4)
Oil temperature lights (2)
Ammeters (2)
Engine oil pressure gauge (2)
Main oil temperature gauge (2)
Oil content gauge (2)
Fire warning lights (2)
Electrical panel*

g. Navigation Communication

The control cabin has been located to ensure maximum all-round vision, but for operations at night or in conditions of poor visibility the Voyageur can be equipped with a Decca Marine Radar Model D202. This includes the scanner, power supply unit, transceiver, and display console.

Navigation lights will be installed on the port, starboard, and stern of the vehicle.

h. Fire Detection and Extinguishing

The engines are completely protected by a self-resetting continuous wire fire detector attached to the engine. Warning lamps in the control cabin are lit when overtemperatures are sensed. The fire extinguisher bottles are actuated by the operator and their contents are discharged through spray rings onto the engine and gearbox. Single or double shots can be fired into any engine. Hand fire extinguishers are provided at strategic points in the cabin.

i. Emergency Equipment

Emergency equipment (life jackets, lifebelts, flares, first aid kit, etc.) will be installed in accordance with U.S. Coast Guard hovercraft requirements.

j. Marine Equipment

The craft is provided with four towing eyes at the bow and two at the stern. Anchors, chocks, and bollards are installed to facilitate handling and mooring.

Performance

The following charts provide preliminary performance estimates for a range of operating weights for the Voyageur (Figures A-7 to A-16). These estimates are derived from experience with the Bell SK-5 and from extensive scale model tests in the Bell Air Cushion Vehicle Laboratory. All performance, except where noted, is provided for calm water and still air conditions at a sea-level standard day temperature of 59°F (15°C). In the Voyageur integrated lift and propulsion system, the power required for forward propulsion varies with forward speed and the amount of power available for the lift fans will vary with speed for a constant total power output from the engines.

*BAC Proprietary Information

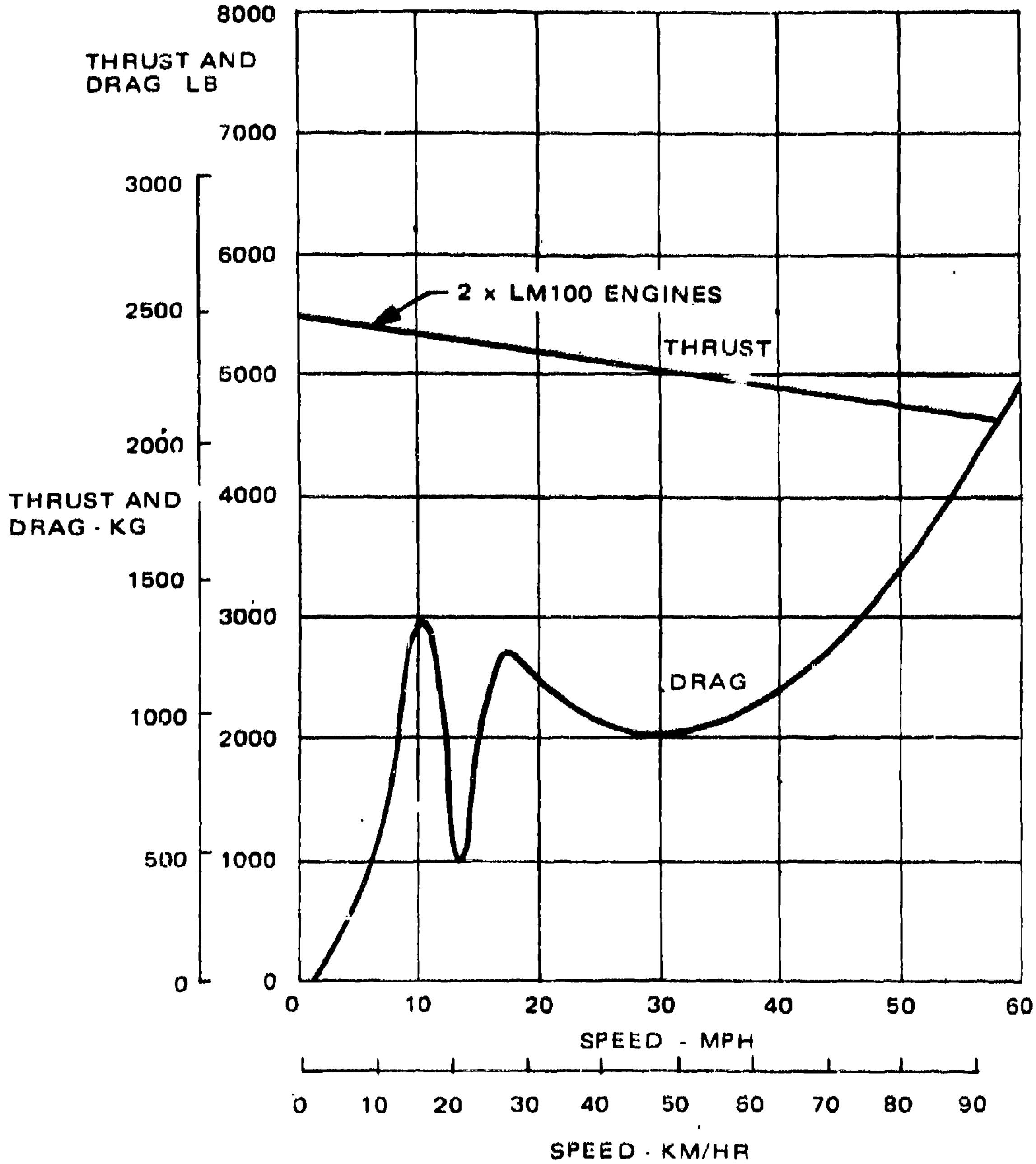


Figure A-7. Model 7380 - Drag versus Speed at 68,000 lb in Calm Water (Atmospheric Condition 59°F – Sea Level)

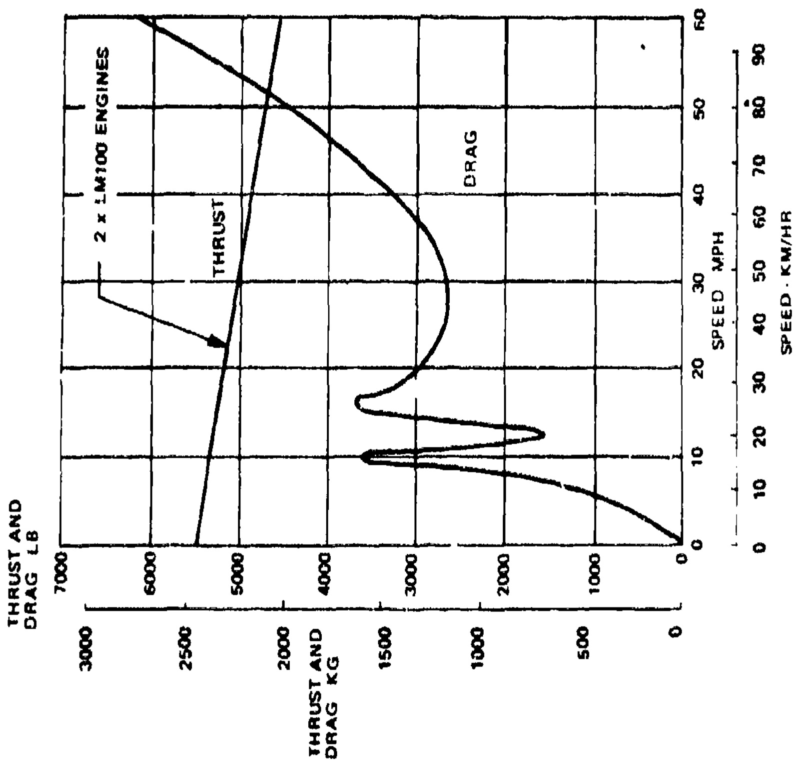


Figure A-8. Model 7380 – Drag versus Speed at 78,000 lb in Calm Water (Atmospheric Condition 59°F – Sea Level)

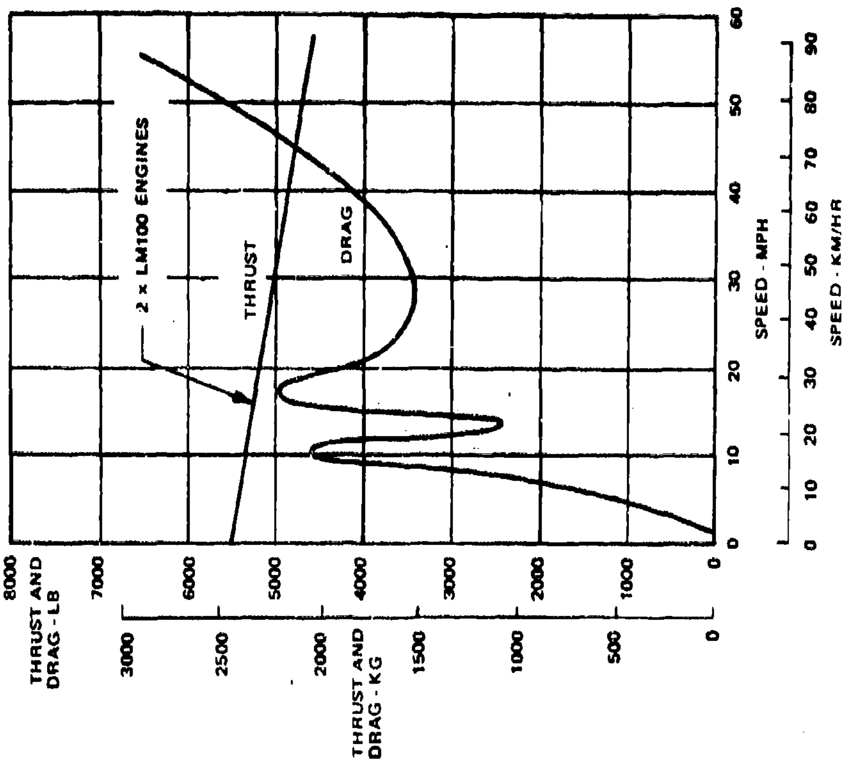


Figure A-9. Model 7380 – Drag versus Speed at 88,000 lb in Calm Water (Atmospheric Condition 59°F – Sea Level

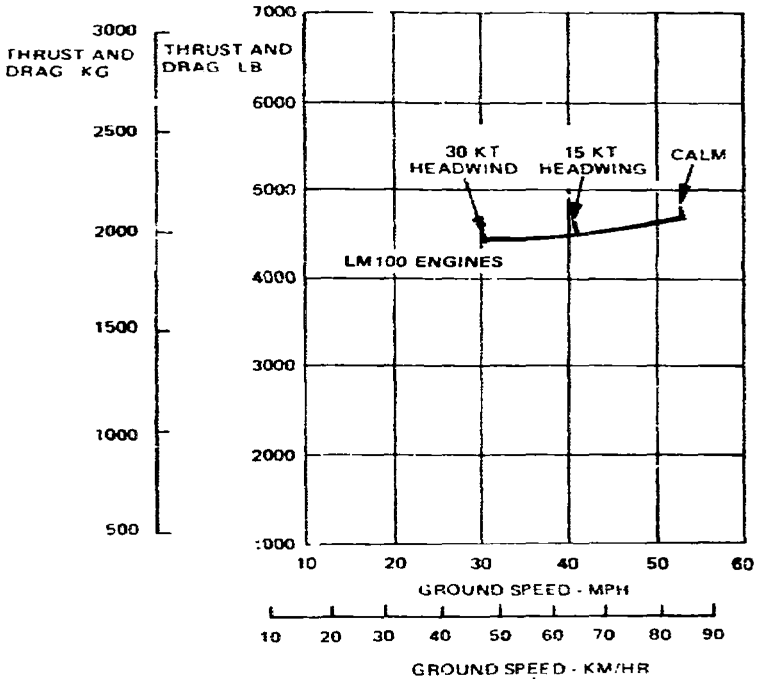


Figure A-10. Model 7380 - Groundspeed Overland for Various Windspeeds (Independent of Gross Weight)

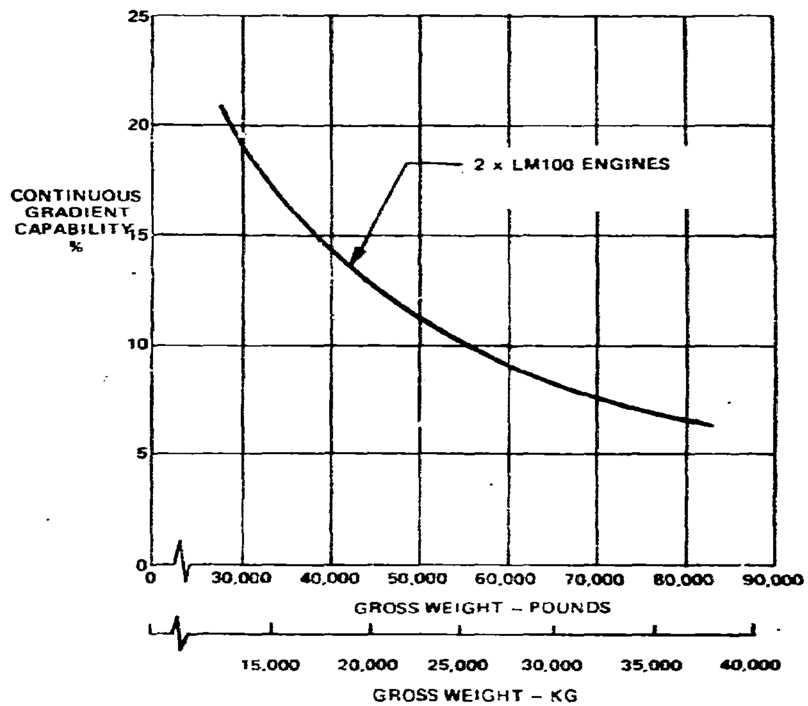


Figure A-11 Model 7380 Continuous Gradient Capability versus Gross Weight

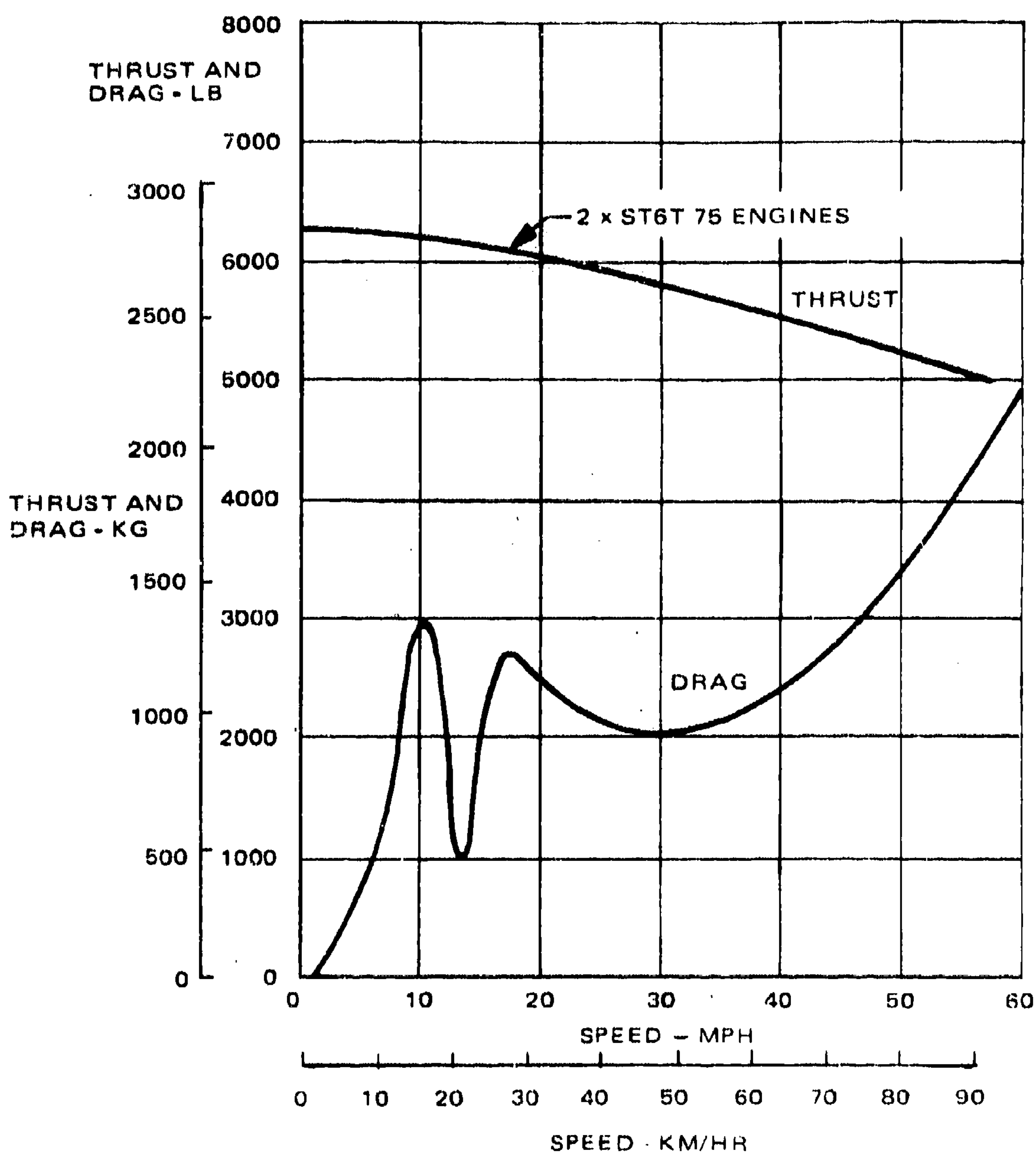


Figure A-12. Model 7380 - Drag versus Speed at 68,000 lb in Calm Water (Atmospheric Condition 59°F - Sea Level)

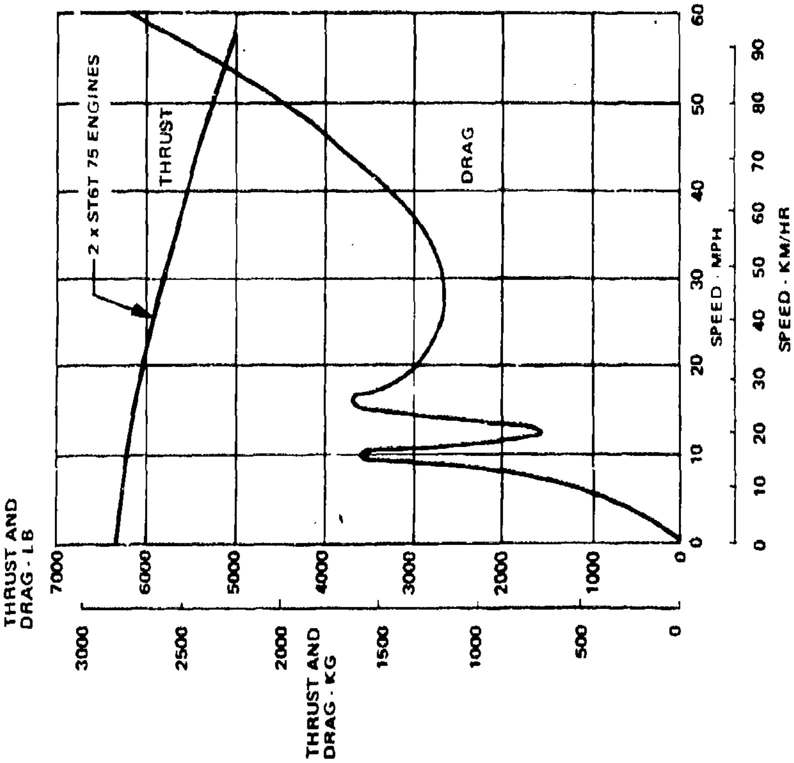


Figure A-13. Model 7380 - Drag versus Speed at 78,000 lb in Calm Water (Atmospheric Condition 59°F - Sea Level)

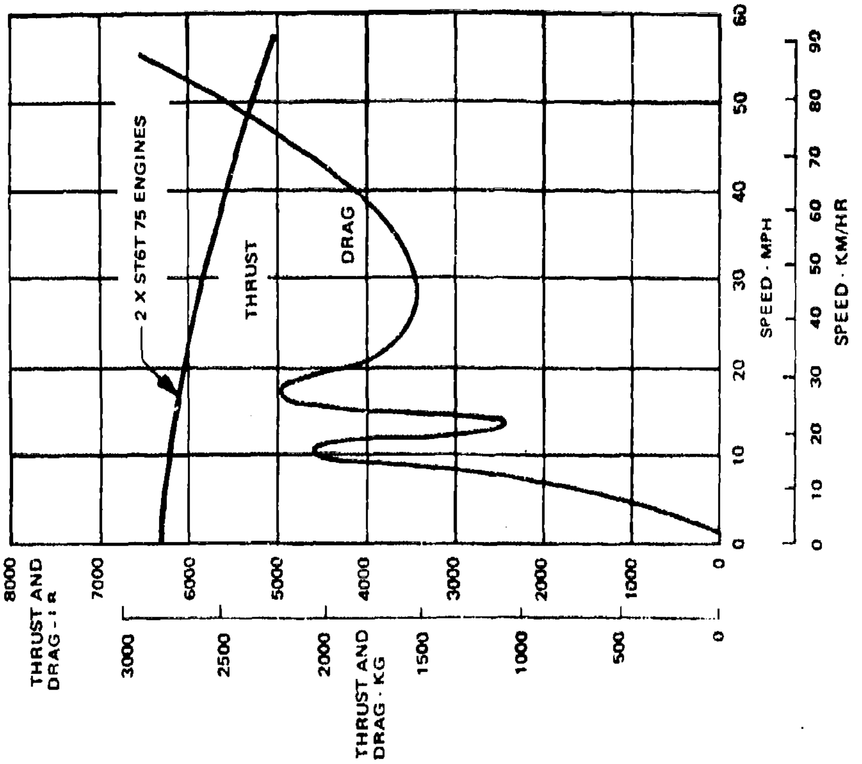


Figure A-14. Model 7380 - Drag versus Speed at 88,000 lb in Calm Water (Atmospheric Condition 59°F - Sea Level)

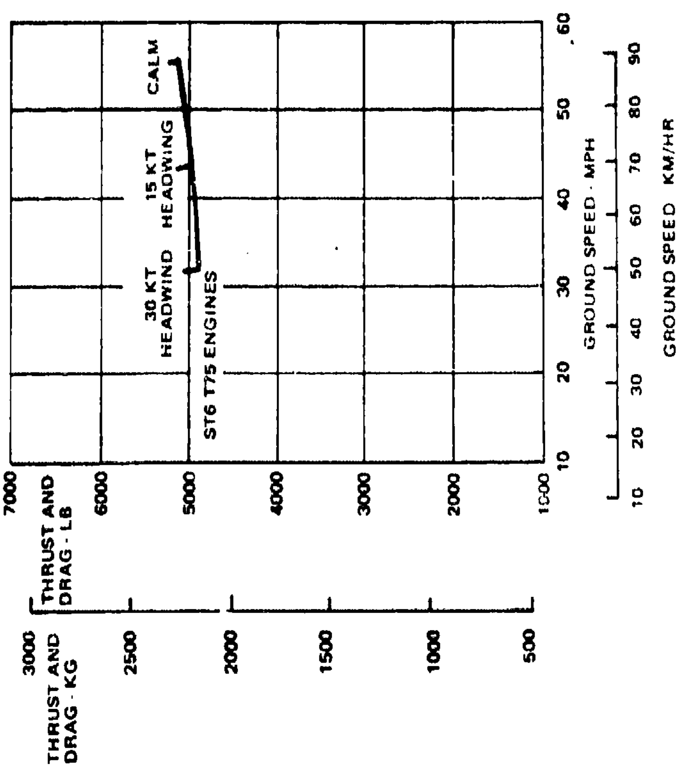


Figure A-15. Model 7380 - Groundspeed Overland for Various Windspeeds (Independent of Gross Weight)

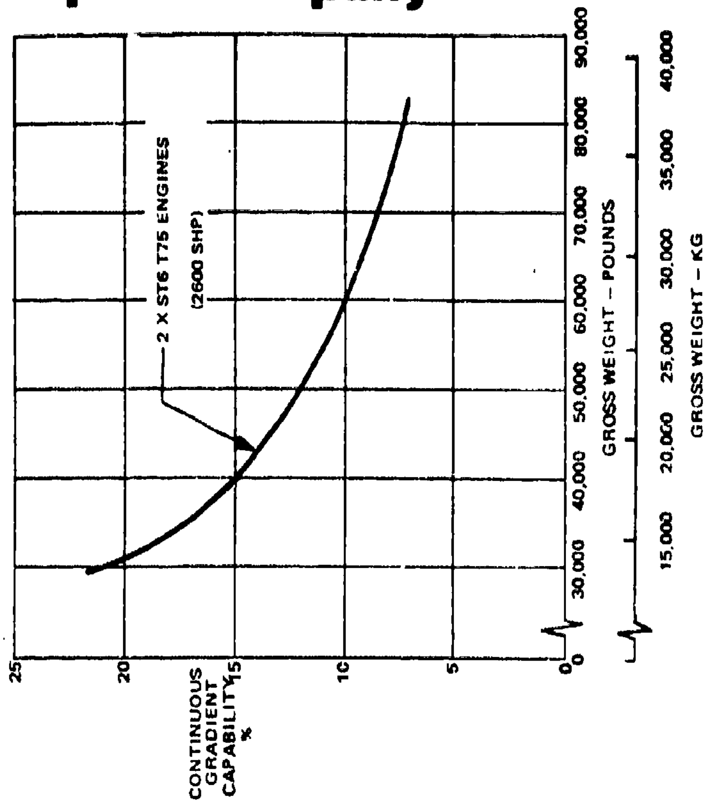


Figure A-16. Model 7380 - Continuous Gradient Capability versus Gross Weight

APPENDIX B

ACV Requirements Questionnaire

CONTACTS

Fletcher, J.O.	Campbell, B.
Moulton, K.	Martin, P.
Kordenbrock, J.U.	Buck, B.M.
Sater, J.E.*	Coachman, L.K.
Ostenso, N.A.	Goddard, W.B.
NASA	Hunkins, K.
NOAA	Pander, E.
Brewer, M.C.*	Ramseier, R.
Schindler, J.F.*	Welser, H.
Allen, M.B.*	Smith, J.
Knodle (Cdr.)*	Weeks, W.
Wittmann, W.I. - NAVOCEANO*	Weller, G.
Untersteiner, N.	Wentink, T.*
Stateman, M.*	Strother, (Lt.) - USA*
Heiberg*	Landre (Col.) - USA*
Haugen*	Gajnon - CRREL*
Francois, R.E.	Liston - CRREL*
	Lyons, Bell Aerospace

*Interviewed

SEV QUESTIONNAIRE

MISSION PROFILE

Name:
Organization: Date:
Address: Telephone:

---

1. Types of Mission and/or tasks
   A. D.

   B. E.

   C. F.

2. Duration of Mission - Days and/or hours
   A. D.

   B. E.

   C. F.

3. Multimission Compatibility - Yes or no or other

4. Total Scientific Instrumentation Requirements

   A. Space B. Weight C. Power Supplies. AC/DC Other

5. Special Accessory Equipment Booms, Winches, Launchers, Others

6. Laboratory Personnel Workspace Requirements

7. Total Scientific Personnel Per Mission (P.I., Technicians, Field Assistants)

8. Table of Scientific Equipment (Type, Model Number, Function, Power Needs) Describe in detail. Use additional sheets if necessary.

OPERATION/LOGISTIC REQUIREMENTS

A. Vehicle Base Location

B. Garage Facilities for 64'Lx33' Wx22'H SEV

C. Docking Facilities Beachhead, ramps, aprons, etc.

D. Fuel Sources JP4, JP5, MOGAS, AVGAS, Diesel

E. Refueling Procedures and Equipment Barrels, bladders, tanks, etc.

F. Safety Procedures and Regulations Base and SEV operation

G. Environmental Constraints Seasonal, year-round, and daily

H. Operating Personnel Availability (specify skill levels)
Crewmen, ground handlers, maintenance

I. Navigation Aids, types, characteristics, dark operations

J. Communications Air/ground, point-to-point, bands, existing equipment, frequencies of blackouts

K. Support Equipment A. Transportation B. Power supplies C. Workshops

L. Field Support Equipment

M. Special SEV Handling Equipment Gantries, cranes, winches, others

N. Housing Facilities On Board Space type, etc..

O. Other Space Requirements Helicopter pad, medical unit, etc.

P. Cooking Facilities

Q. Water Storage and Ice Melting Capability

R. Other Special Support Requirements

REMARKS AND DETAILS

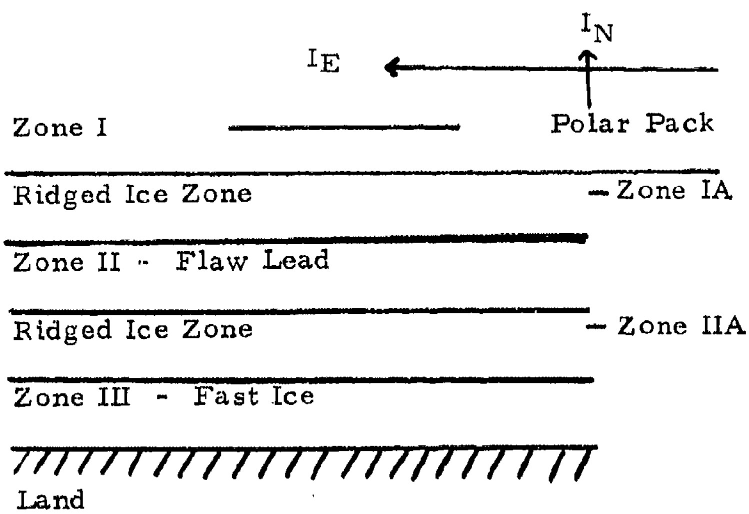
APPENDIX C

Notes on the Time-Space Variations in the Features and Dynamics of the Pack Ice North of the Alaskan Coast

GENERAL CONSIDERATIONS

The dominant ice affecting the North Alaskan coastal waters is the so-called Polar Pack ice which revolves slowly in a circular, clockwise trajectory known as the Pacific Gyral. This 2-3 nm/day, meandering drift is centered at approximately 78N/145W; it has a radius of approximately 250 nautical miles. The Pacific Gyral has been substantiated by the drifts of major U.S. and Russian ice stations, most graphically by T-3, also known as Fletchers Ice Island. T-3, since its first sighting in the late 1940's, has completed more than two revolutions in this Gyral. The predominant stages of ice characterizing this circular cell is multiyear pack ice. Because of the containment, a floe would tend to remain, perhaps forever, in this area. However, because of the tendency for ice to grow more slowly as it gets thicker but with, on the average, a mean annual melt that is relatively fixed at 2 to 4 feet, a multiyear floe tends to rejuvenate itself in this area after reaching an equilibrium thickness of approximately 10 feet over a period of what is believed to be about 3-4 years. The annual, monthly, daily, and even hourly variability in the positioning of this Gyral is great. In addition, rates of movement within the Gyral display the same wide variations. As a result, Figure 1 is presented to facilitate further discussion of time-space variability in ice features and characteristics.

FIGURE 1 Schematic Diagram of North Alaskan Sea Ice and Drift



(I_N and I_E represent the dominating off-shore and long-shore components, respectively, of the ice drift.)

TABLE I

USUAL THICKNESS (OR RANGE) ATTAINED BY MAJOR ICE STAGES BY ZONE AND MONTH (WITH MEAN MONTHLY TEMPERATURE°F)

	ZONE I				ZONE III				
	New Ice	1st year	Multi-year	Mean Month Temp	New Ice	1st year	Multi-year	Mean Month Temp	
AUG	0-2	0	<6-9	31	0	0	<2-4	39	AUG
SEP	0-8	8	6-9	21	0-2	2	<2-4	31	SEP
OCT	0-17	21	7-10	1	0-12	12	4-6	17	OCT
NOV	0-22	34	7-10	-15	0-18	24	4-7	0	NOV
DEC	0-25	48	8-10	-22	0-22	34	5-8	-11	DEC
JAN	0-27	59	8-10	-28	0-23	46	6-9	-16	JAN
FEB	0-24	68	9-10	-27	0-22	56	6-10	-19	FEB
MAR	0-25	74	9-10	-25	0-22	63	7-10	-14	MAR
APR	0-22	78	9-10	-12	0-17	68	7-10	0	APR
MAY	0-12	81	8-10	14	0-8	69	7-9	19	MAY
JUN	0-2	<72	7-9	31	0	48	6-8	33	JUN
JUL	0		6-9	32	0	0	< 2-4	40	JUL
	(IN)	(IN)	(FT)	(°F)	(.N)	(IN)	(FT)	(°F)	

Zone I, in Figure 1, is dominated by the Pacific Gyral circulation discussed. Not only is this Gyral subject to steady motions varying from 0-30 nm/day, but alternate convergence, divergence, shear, and other dynamic variations such as fracturing and subsequent refreezing of new ice in the openings result. This is especially frequent during the long winter period; to a lesser degree, melting of the ice floes results in the short summer season. As a result, at any one time all stages of development in ice types can and usually are present in this Zone I regime. Usual thicknesses attained in these various stages are indicated in Table I.

A second major zone in the North Alaskan ice, Zone II, is also significantly influenced by the periodic migration, discussed above, of the Pacific Gyral toward and away from the Alaskan coast. These migrations when moving off-shore tend to create a broad coastal lead or "flow zone." The width and continuity of this lead depends upon the duration of the off-shore motion together with its intensity. Ice motion, of course, is determined by a complex interaction of many factors of which the current, and even more important the wind stress, is believed to be dominant. In general, this lead parallels the North Alaskan coast line. Depending on particular surface atmospheric circulation patterns which have prevailed, the lead may be wide in some portions whereas in others it may be virtually nonexistent at any one time. More specific widths will be offered for this Zone II flaw lead regime in the discussion on seasonal considerations contained below.

A third major subregime, Zone III, of the North Alaskan ice is the immediate coastal area, generally extending seaward to the 10-fathom curve. Here ice tends to form first at the immediate coastline in the late September and early October period. After November, however, formations which had earlier been subject to the disintegrating influences of off-shore winds, tend to become permanent and accelerated. The steady growth of fast ice after this time expands seaward and usually follows the rate specified for first-year ice under Zone III in Table I; it tends to become somewhat thinner to the seaward. This coastal fast ice, when well developed, tends to act as a buffer in preventing incursions of the polar pack ice, thus preventing severe near-shore scouring by ice keels (the underwater portions of pressure ridges and hummocks). Growth of the coastal fast ice reaches a maximum in early May. As a result of warming over the tundra in June, together with a sometimes rapid melting of the snow and glaciers, draining from the Brooks Range further to the south at this time, a mechansim for rapid melt and disintegration of this Zone III fast ice is provided. After its melt, usually total by early July, either of two conditions prevail during the summer or navigational season. A completely ice free condition may exist from the coast to the polar pack itself; on the other hand, with persistent and intense on-shore prevailing winds, the pack ice may be compressed along the entire length of the North Alaskan coast line. This latter case, fortunately, is the more unusual. Only in some seasons -- about once every 7-10 years -- do such severe conditions persist for a period of up to 45 days. More normally, an off-shore component exists in the prevailing wind stress and, as a result, there is a tendency for an incomplete or broken lead to exist between the coastal line and the off-shore pack.

In addition to the new ice, first-year ice and multiyear ice already discussed a relatively rare but sometimes troublesome additional ice type occurs at times in this Zone III regime. Fortunately, from the point of view of surface ship and submarine operators as well as of those interested in constructing terminal facilities for SEV purposes or for those wishing to conduct off-shore drilling through the fast ice, icebergs are unknown through the entire Pacific Gyral and extending through the Zone II and Zone III regimes. An exception, however, is the shelf ice fragments or "ice islands" that result from periodic calvings and subsequent drifts or fragments from the Ward Hunt Shelf ice. This 180-foot-thick, mainly glacial ice front is located along the northernmost coastal area of Ellesmere Island in the Canadian Archipelago. About every 5-10 years there is a fragmentation along this shelf ice front. The Pacific Gyral circulation tends to carry such fragments southward along the Queen Elizabeth Islands, past Banks Island, and on occasion fragments are thrust into the Zone II and III circulation patterns along the North Alaskan coast. Depending on the off-shore/on-shore component of circulation within this Gyral, shelf ice fragments may also ground on occasion; T-3 near Barrow and other occurrences of this nature at Prudhoe Bay in 1970, for example, have documented this type of a trajectory.

SEASONAL CONSIDERATIONS OF ZONE I AND II

Some imporatnt generalizations can be made concerning the brief summer period in the multiyear ice dominating Zone I circulation. After about 31 May occasional periods of intensive melt do occur. These periods result in the ice becoming covered with superficial melt pools. Depending upon the duration and persistence of such above freezing temperatures, coupled with other factors such as the existence, at the same time, of divergent floe and the past history of snowfall, these melt pools may erode completely through resulting in the total disintegration of not only new and first year ice forms but, on occasion, of multiyear ice floes as well. The tendency for this melt and disintegration phenomena becomes less as the summer season progresses, and after early September they no longer occur and disintegration halts. During this brief summer period ranging from early July to early September, fractures (leads and polynas characterizing the pack ice resulting from divergent and shearing motions) tend to be more frequent and stay open for longer periods (completely open rather than covered with new ice forms). In Zones II and III the expectancy of coverage with new ice and first-year ice forms occurs earlier; dates of onset and duration of melt may be acquired from a combination of considerations listed in Table I.

In winter the mean width of the lead or flow zone dominating Zone II varies from a few nautical miles to as much as 10 or 20; on rare occasions much wider extent has been indicated by both aerial reconnaissance and satellite imagery. In the summer this Zone II may stretch for the entire length of the North Alaskan coast line; a much shorter length however, is more usual, on the order of 10-30 miles with multiyear ice frequently pinching off this lead either near Point Barrow or further to the east near Barter Island.

In summer, Zone III is completely obliterated. Because of the tendency of the level portions of ice to melt very rapidly if a past winter's growth of 4 feet or more has not been realized, there is frequently a summer situation where a greater percent of rough ice grounds along the coast than during winter. This concentration of pressure ridge fragments is sometimes observed in the Barrow vicinity, and it provides a severe obstacle to surface shipping.

In both summer and winter Zone II tends to curve to the northward as one proceeds west of the Point Barrow meridian.

RIDGED ICE ZONES

In addition to the subregimes discussed above, two other areas are worthy of note and are indicated in Figure 1. Zone IA is an area of heavily ridged ice believed to be the result of alternate opening and, more important, closing of the Zone II flaw lead. Depending on the number and intensity of such occurrences, this zone may vary from a few to tens of miles in width. On the average it is about 20 miles wide and consists of mostly east-west oriented fracture zones, frequently in the form of refrozen, connected diamond-shaped polynas together with heavy parallel lines of ridged ice (ridged ice zones).

Finally Zone IIA must be cited. This is the area occurring between the fast ice (Zone III) and the flaw lead (Zone II). Where the fast ice is attached to the land, alternate on-shore motion tends to create lines of ridging in more nearly the same location as they occur from time to time. As a result this region tends to vary between 1 and 10 nautical miles; more usually it is about 2 miles in width. Grounding of hummocks which attain drafts of about 140 feet on occasion occur only here (not in Zone IA) and in those portions of the region having such depths. Winter pressure ridges are more usually 55 to 75 feet, however, and grounding at these depths tends to keep the fast ice of Zone III flat and largely free of fractures.

CONCLUSION

In conclusion, the pack ice north of Alaska must be thought of first as one of the most dynamic regimes of all those comprising the Arctic Basin and its marginal seas. Of all the latter, only the Chukchi-Beaufort Seas are so widely and unprotectedly influenced by the motion of the Polar Pack itself.

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